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Environmental Use: Chapter 24
The Iron and Steel Industry**

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16. ABSTRACT The catalog was developed to aid in defining the environmental impacts of U.S. industrial activity. Entries for each industry are in consistent format and form separate chapters of the catalog. The Iron and Steel Industry encompasses a variety of processes for transforming iron ore into fabricated iron and steel products: most large steel mills operate by-product coke plants that produce metallurgical coke and coke by-products. The industry is divided into five segments: ore preparation, coke production, coke by-products recovery, pig iron production, and steel manufacturing. Five process flow sheets and 30 process descriptions characterize the industry. For each process description, available data is presented on input materials, operating parameters, utility requirements, and waste streams. Related information presented as appendices, includes raw materials, company, and product data.			
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FOR ENVIRONMENTAL USE:
CHAPTER 24. THE IRON AND STEEL INDUSTRY

by

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IRON AND STEEL INDUSTRY

INDUSTRY DESCRIPTION

The Iron and Steel Industry encompasses a variety of processes for transformation of iron ore into fabricated iron and steel products. In addition to the manufacture of steel products, most large steel mills operate by-product coke plants producing metallurgical coke and coke by-products. The industry is divided into five segments: 1) ore preparation, 2) coke production, 3) coke by-products' recovery, 4) pig iron production, 5) steel manufacturing.

The processes involved in ore preparation are iron ore beneficiation including mining, upgrading and concentration operations; and agglomeration or preparation of the ore for charging into a blast furnace.

In the coking segment, mined metallurgical coal is prepared for charging into coke ovens, coked (nondestructive distillation) and quenched. Coke-oven gas, a by-product from coking, is treated for by-product recovery and also used as a fuel. Crude tar, ammonia, light oil, phenol and other by-products of coking are further processed, depending on plant design and on markets for specific products.

Pig iron production involves production of pig iron from iron ore, coke and limestone in a blast furnace.

The steel manufacturing segment primarily involves production of steel from pig iron and scrap in electric, open-hearth or basic oxygen furnaces and finishing operations in which raw steel is shaped, rolled drawn, coated or otherwise treated to produce sheets, strips, plates, pipe, wire or other forms of steel products.

Many steel plants generally do not incorporate all combinations and variations of the operations described in this document. The industry encompasses a variety of plants ranging from small to very large and

from older marginally operating facilities built early in the century to more efficient modern facilities built or upgraded in recent years. Table 1 shows the numbers of companies involved in various phases of the integrated iron and steel industry.¹

Table 1. COMPANIES ENGAGED IN
IRON AND STEEL OPERATIONS, 1970

Operation	Number of companies
Operate steel facilities	200
Pig iron (for sale and for in-plant use)	30
Coke	48
Raw steel	95
Carbon quality steel	78
Alloy steel	54
Stainless steel	28
Steel bars	50
Wire products	50
Plates	26
Pipe and tubing	60
Cold rolled sheets	25
Tool steel	15

In 1973, the iron and steel industry employed 672,695 workers, of whom 511,220 were hourly wage employees and the remaining were salaried.² In 1974, iron ore mining and preparation units employed 19,804 people of which 2,460 were in underground mines, 8,202 in surface mines and 9,142 in preparation mills.*

* Information provided by L.P. Larson, Health and Safety Analysis Center. Mining and Safety Administration. United States Department of Interior, Washington, D.C. July 22, 1974.

Total U.S. iron ore requirements in 1973 for blast furnace feed and other minor uses were 139.24 million tons.* Of this amount, 92.24 million tons* were produced domestically and 47 million tons* were imported. Canada supplied approximately 22.68 million tons,* Venezuela more than 11.79 million tons,* Brazil 2.9 million, Liberia 2.45 million, Peru 1.35 million, Austria 453.6 thousand, Sweden 305 thousand and Chile 272.15 thousand tons,* Consumption of iron ore increased to 147 million tons* in 1974, and blast furnace pig iron output was 97.44 million tons.* In the same year, steel production totalled 132 million tons.* Production in open-hearth furnaces was 36.1 million tons,* in basic oxygen furnaces 82.91 million tons,* and in electric furnaces 28.86 million tons.*³ There were 48 coke plants at integrated iron and steel facilities in 1974. Total coke production in that year was 55.87 million tons,* of which 51.2 million tons* were used in blast furnaces.⁴ Table 2 shows the number of coke plants recovering various by-products.⁵

Major portions of iron ore come from the Lake Superior region. Other areas of iron ore production are California, Utah, Wyoming, Texas, Missouri, Alabama, Pennsylvania, and New York. Combined output of these areas makes the U.S. the world's third largest producer of iron ore.³

Most of the major steel companies own or control domestic mines that supply at least part of their ore needs. These companies also have invested substantially in iron mines in Canada, Venezuela, Chile, Brazil, Liberia, and Australia. The major companies producing iron ore in Canada are owned or controlled principally by U.S. interests.⁶ It is estimated that captive mines furnish about 85 percent of the ore used by the domestic iron and steel industry.

Trends in iron ore mining are significant. Taconite pellets are replacing iron ores, huge open-pit mines are replacing underground mines and mining is changing from a seasonal to a year-round basis. Changes in steel manufacturing operations are equally significant. Oxygen furnaces, and to a lesser degree electric furnaces, are rapidly replacing open

* Metric tons (1000 kg or 2205 pounds) are used throughout this report.

Table 2. NUMBER OF COKE PLANTS ENGAGED IN RECOVERING BY-PRODUCTS
IN 1974.

By-product recovered	Number of plants		
	Furnace ^a	Merchant ^b	Total
Ammonium sulfate	41	2	43
Ammonia liquor (NH ₃ content)	2	4	6
Diammonium phosphate	1	-	1
Crude coal tar	48	14	62
Creosote oil, straight distillate	5	-	5
Crude chemical oil (tar acid oil)	3	4	7
Sodium phenolate (carbolate)	15	1	16
Phenol	2	-	2
Cresols	1	-	1
Cresylic acid	1	-	1
Pitch	6	-	6
Crude light oil	45	6	51
Benzene, all grades	18	1	19
Toluene, all grades	13	1	14
Xylene, all grades	13	1	14
Solvent naphtha, all grades	10	1	11
Intermediate light oil	10	1	11
Naphthalene	15	-	15
Picolines	1	-	1
Sulfur	1	-	1

^aOwned by iron and steel companies and produce blast furnace coke for their own use.

^bAssociated with chemical companies or gas utilities, or operate to produce coke and coal chemical materials for sale to steel companies or foundries

hearth; continuous casting eliminates some of the conventional steel mill operations such as ingots, soaking pits, and slabbing, blooming, or billet mills. In addition, mills are producing all grades of steel with fewer men.⁶

In the U.S., most steel plants are located in areas of fairly dense population. More than 200 companies that make iron and primary steel mill products operate in 37 states.¹ About 65 to 70 percent of the Nation's steel industry is situated in the great industrial complex surrounding the lower Great Lakes ports in Illinois, Indiana, Michigan, Ohio, and western Pennsylvania. Large integrated steel mills are also operated in northern New York, eastern Pennsylvania, eastern Maryland, and the Birmingham district of Alabama; relatively small integrated steel mills are operated in southern Illinois, Texas, Colorado, Utah, and California.

In 1980, the U.S. must produce 175 million tons* of raw steel if economic growth is to be maintained. Consumption of iron ore will increase substantially to provide for 10 million tons* more of blast furnace output as well as the amounts needed (possibly as much as 5 million tons*) for direct reduction.³ By the year 2000, the demand for iron ore in the U.S. is projected to rise to 215 million tons* and domestic production of ore to 127 million tons.*⁷ The projected total coke consumption in 1980 is estimated to be about 70 million tons.*⁸

Raw Materials

Iron ore, the main raw material of the industry, is a mixture having varying quantities of mineral impurities. Contaminants that can be present in iron ore include phosphorous, sulfur, titanium, vanadium, zinc, copper, chromium, nickel, arsenic, lead, tin, and cobalt.⁶ Tables 3 and 4 give typical analyses of different iron ores.^{9,10} Details of the major types of ores, and their characteristics and data on the consumption of other raw materials used are given in Tables A-1 and A-2, Appendix A. At coke producing plants, low-sulfur coal is the main raw

* Metric tons (1000 kg)

Table 3. IRON ORE ANALYSIS

Kind of ore		Composition, percent						
Range	Name	Fe	SiO ₂	Al ₂ O ₃	CaO	MgO	P	Mn
Mesabi	Hanna	53.29	8.04	0.43	0.15	0.10	0.041	0.39
		to 54.96	to 10.01	to 0.37			to 0.047	to 0.60
Menominee	Weirton (Michigan)	51.5	3.02	2.17	0.65	0.90	0.464	0.17
		to 54.90	to 4.23	to 2.61			to 0.542	to 0.33
Labrador		48.58	3.84	0.73	0.02	0.02	0.054	0.56
		to 55.51	to 6.84	to 1.08	to 0.15	to 0.05	to 0.117	to 4.50

Table 4. ANALYSIS OF TACONITE ORES

Component	Avg. percent by weight
Total Iron	32.0
Magnetic Iron	24.5
Silicon Dioxide	45.2
Manganese	0.3
Aluminum Oxide	0.8
Calcium Oxide	2.3
Magnesium Oxide	3.0
Phosphorus	0.05
Sulfur	0.02
Titanium Dioxide	Trace

material. Details of coke production for use in coke ovens is given in Table A-3.

In addition to the ore materials, iron production requires fluxes such as silica, limestone or dolomite. Various ferroalloys (as alloying agents) and all types of metal scrap are used in steelmaking. The processes require large amounts of fuel, mainly coke and oxygen. Statistics on energy and water consumption in the steel industry are given in Tables D-1 and D-2. Appendix D.

A number of metallic elements and compounds may be added to molten iron or steel to effect specific properties in the end products or to coat finished products. Additives are used to remove gases, decrease inclusions, counteract harmful effects of sulfur, or change the characteristics of the metal. The more common additives are aluminum, chromium, cobalt, columbium, copper, lead, magnesium, manganese, molybdenum, nickel, carbon, phosphorus, boron, silicon, tin, titanium, tungsten, and vanadium.

Products

The iron and steel industry produces coke; various chemicals recovered from the by-product coking process; pig iron; and various grades of basic steel in such shapes as ingots, blooms, billets, plates, structurals, bars, wire, coils, sheet, tubing, tinplate, galvanized, and other.

Pig iron is the product of the blast furnace formed by smelting iron ore with a carbonaceous reducing agent, usually coke. About 90 percent of the pig iron produced in the United States is consumed in making steel; the remainder is used for iron castings.

Steel is a refined iron-base alloy containing up to 1.7 percent carbon. Some principal types of steels are: 1) carbon, 2) manganese, 3) nickel, 4) nickel-chromium, 5) molybdenum, 6) chromium-molybdenum, 7) nickel-chromium-molybdenum, 8) nickel-molybdenum, 9) chromium, 10) chromium vanadium, 11) tungsten chromium, 12) silicon manganese, 13) low alloy high tensile, 14) stainless, 15) boron intensified, 16) leaded. Hundreds of different grades of steel are manufactured.

Small amounts of gold, silver, sulfur, copper, cobalt, and phosphate minerals are recovered occasionally as by-products and coproducts during iron mining operations at a few domestic deposits. Manganese is often a coproduct.⁶

Blast furnace slags are used principally in the construction and maintenance of roads, buildings, railroads, and airports; in manufacture of mineral wool; and to some extent in agriculture. Steel slags either alone or in blends with blast furnace slags, are used similarly.⁶

The integrated iron and steel industries produce coke and recover by-products such as ammonia, tars, light oils, phenols, and benzene.

Companies

In 1974 there were more than 86 integrated iron and steel companies in the U.S. and more than 200 operating entities. The seven largest companies are listed in Table 5.¹¹ Table C-1 lists all companies in the U.S. that produce iron and steel. These companies operated 164 blast furnaces and four direct reduction ore plants (Table C-2).

The 45 ore producing companies as listed in Table C-3 are closely associated with the steel companies. The largest mining areas are in Minnesota, with three companies, U.S. Steel's Minntac Plant, Republic and Armco's Reserve Mining Co., and Erie Mining Co. (controlled by 5 companies), producing approximately 40 percent of the ore. Table C-4 lists the recent iron mine and plant expansions in the United States. A list of the captive steel coal mines in the United States supplying basically coal for coking purposes is given in Table C-5.

Most coke plants were also operated by steel companies at 63 locations. Operations in Ohio and Pennsylvania account for 25 of these plants, as shown in Tables C-6 and C-7, Appendix C.

Environmental Impact

Wastes from the various operations in steelmaking vary widely in characteristics and in volume. The main environmental concerns at iron and steel plants pertain to air and water. An estimated 14.4 million tons* of atmospheric particulate and 11.3 tons* of water-borne suspended

* Metric tons (1000 kg)

Table 5. SUMMARY OF SEVEN LARGEST STEEL COMPANIES

Company and headquarters	Number of steel mills	Tons of steel produced in 1971 ^a	% of U.S. steel production 1971
United States Steel Corp. Pittsburgh, Pa.	15	27,200,000	22.5
Bethlehem Steel Corp. Bethlehem, Pa.	8	17,400,000	14.4
Republic Corp. Cleveland, Ohio	9	8,700,000	7.2
National Steel Corp. Pittsburgh, Pa.	3	8,600,000	7.1
Armco Steel Corp. Middletown, Ohio	8	7,900,000	6.5
Jones & Laughlin Steel Corp., Pittsburgh, Pa.	3	6,600,000	5.4
Inland Steel Co. Chicago, Ill.	1	6,400,000	5.3
Totals	47	82,800,000	68.4

^a Metric tons (1000/kg).

solids were discharged from steel mills in 1971.¹² In addition to particulates, fluorides, carbon monoxide, hydrocarbons, and sulfur oxides are emitted to a lesser extent by the various steelmaking processes.¹¹ The uncontrolled emissions of selected pollutants discharged from the iron and steel industry in 1971 and the amounts discharged from the industry by region are given in Tables E-1 and E-2, Appendix E.

Coal mining for coke production, and iron ore mining and beneficiation produce large quantities of tailings and potential water pollution problems. These problems can vary from acid mine drainage to asbestos-like fibers in ore tailings.

The principal air pollution problems resulting from coke production are sulfur dioxide from combustion of the coal in the coke ovens, particulate and gaseous emissions from ovens during charging and pushing, leakage from doors and lids; and emissions from quenching of the coke with waste water. Carcinogenic hydrocarbons in coke oven smoke have been reported. Principal water pollution problems in coke plant operation are in the wastes from ammonia stills and light oil decanters, which average about 185 liters per ton of coal carbonized and contain phenol, ammonia, cyanides, chlorides, and sulfur compounds.¹³ The coal tar storage area is also a major source of hazardous emissions in a coke plant. Many control measures are practiced to curb emissions from coke plants. Since the coke breeze from the various operations is either used within the plant or sold, coke production does not constitute a solid waste problem.

The iron and steel industry, one of the largest users of water in America, requires 110,000 to 150,000 liters of water to produce a ton* of steel. These immense volumes of water accumulate many tons of contaminants including metallic particles, dirt, oil, and grease.¹⁴ The use of water for cooling causes significant thermal pollution problems. Typical coke plants produce about 13 liters of wastewater per ton of coal processed.¹⁵

According to recent tests on process stream and stack sampling conducted at a major northwest Indiana steel company, the steel industry

* Metric ton (1000 kg)

is among the leading contributors to the cadmium burden in the environment. The other metallics released include lead and zinc. Potential mechanisms for the release of cadmium, lead, and zinc-bearing dust in steelmaking are associated with six major processes: agglomeration plant, blast furnace, open-hearth furnace, basic oxygen furnace (BOF), and electric furnace. Release of these metals is mainly attributed to No. 2 scrap steel (containing galvanized and plated metal) melted in the open hearth, BOF, and electric furnaces; and existence of these metals in trace quantities in the iron ore, limestone and coal used in these processes.¹⁶

Table E-3, Appendix E gives the average cadmium, lead and zinc contents of the emissions from different processes of iron and steel industry.

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INDUSTRY ANALYSIS

The environmental impact of all aspects of the iron and steel industry has received wide attention and has been the subject of many industry and governmental studies. Emission data, though variable, is available.* Information for this study was largely obtained from literature.

Description of five industry segments are presented: ore preparation, coke production, by-product recovery, pig iron production, and steelmaking. Each segment begins with a basic raw material and ends with a finished product. Products from one segment frequently become the raw material for another segment.

* A special scientific group has been formed consisting of representatives of the American Iron and Steel Institute and U.S. EPA to clarify the emission data controversy.

ORE PREPARATION

Figure 1 illustrates the processes in ore preparation including agglomeration. The processes in the order of their discussion are:

Ore Concentration

1. Mining
2. Preliminary ore preparation
3. Ore concentration

Agglomeration

4. Sintering
5. Pelletizing
6. Nodulizing
7. Briquetting

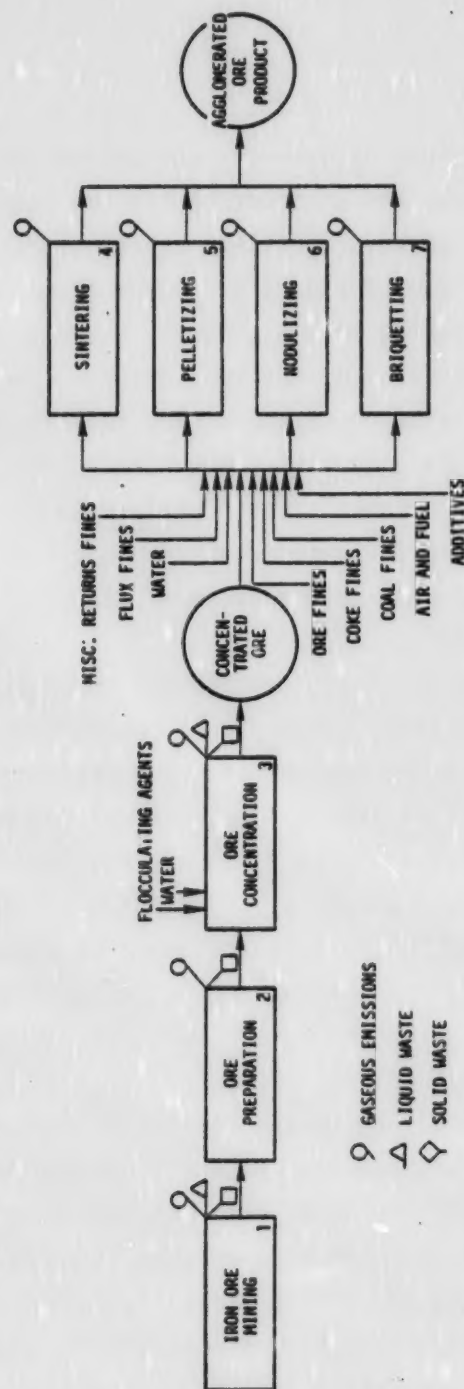


Figure 1. Iron ore production.

Note: Material handling and storage which is not shown on the flow sheet is required throughout pig iron production and has fugitive emissions, liquid waste and solid waste.

Mining

1. Function - Ore is mined by open-pit and underground methods, depending upon the shape, depth, and attitude of the ore body being mined. Open-pit mining is used whenever possible since underground mining requires a larger investment per ton of capacity. Open-pit mining in colder climates may be shut-down during severe winters, whereas underground mining can be maintained, if so desired, the year around. Ores are extracted by several methods utilizing the basic mining techniques of drilling and blasting, and heavy machinery to convey the loose ore into transfer systems. The mining of taconite poses some special problems because of its extreme hardness. Ore is transported from mines to mills by rail cars, trucks, truck-trailers, belt conveyors, ore boat carriers or combinations of these carriers.

In underground mining, ore is transported to the surface by rail trams, trackless shuttle cars, scrapers, or conveyor belts.

2. Input Materials - The formations of ore contained in hematite and magnetite consist largely of iron oxides, carbonates, and silicates. These ores contain approximately 25 to 30 percent iron.¹ Iron content of taconite is much lower. In 1971, 2.45 tons* of crude ore was mined per ton of usable product.² Drilling and dynamite blasting are utilized.

3. Operating Parameters - Mining is done at ambient conditions.

4. Utilities - The basic utility needs are electricity, water and fuels for mobile equipment and drilling.

5. Waste streams - The mining wastes consist of vast quantities of overburden, rock, and low-grade ore which are removed in the beneficiation mills and concentration of the mined ore. In the Mesabi Range area of Minnesota alone, mining waste dumps cover some 55 million square meters.³ Iron mines are responsible for little air pollution other than fugitive dust emissions. Transportation of ores also entails significant emissions of fugitive dust. It is estimated that as much as 2 percent of the ore

* Metric tons (1000 kg)

can be lost in transport in open cars unless dust-suppressing chemicals are added. In open-pit mining, water causes many problems; whenever possible, water is collected in sumps, pumped from the open-pit mine, and sometimes used as make-up water. Mine water may contain significant quantities of dissolved solids. The quantities and composition of water discharged vary from operation to operation. Table 6 gives the constituents of iron-mine discharges before and after treatment.⁴ Table 7 gives chemical characteristics of settling-pond discharge at one open-pit mine that accumulates water.⁴ Mine water contains varying concentrations of ammonia, nitrite and nitrate, if nitrogen-based blasting agents are used.

6. EPA Source Classification Code - None exists.

7. References -

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Table 6. CONSTITUENTS OF IRON MINE LIQUID DISCHARGES

Parameter	Concentration, mg/l						
	Before treatment			After treatment			
	Min	Max	Avg	No. of samples	Min	Max	Avg
Total suspended solids	1.000	5000.0	371.51	19	1.000	30.0	10.693
Total dissolved solids	140.0	1880.0	436.18	17	100.0	1090.0	390.10
Chemical oxygen demand	0.200	36.0	6.470	10	0.026	42.0	12.116
pH	5.00 ^a	8.40 ^a	7.45 ^a	18	6.800 ^a	8.500 ^a	7.652 ^a
Oil and grease	1.800	9.000	4.511	9	0.400	20.400	4.313
Aluminum	0.003	0.350	0.066	7	0.007	0.350	0.131
Calcium	0.003	256.0	85.39	3	0.002	0.158	0.045
Chromium	0.001	0.010	0.007	9	0.010	0.010	0.010
Copper	0.001	1.000	0.167	12	0.005	0.370	0.120
Iron	0.060	178.0	13.3	14	0.008	2.100	0.446
Lead	0.001	0.100	0.018	9	0.008	0.100	0.023
Magnesium	0.020	118.0	39.35	3	0.008	0.029	0.017
Mercury	0.002	2.00	1.001	2			
Nickel	0.003	0.100	0.024	6	0.010	0.075	0.023
Sodium	0.023	15.0	7.511	2			
Manganese	0.001	18.0	2.462	14	0.001	6.900	1.720
Zinc	0.001	8.0	1.869	9	0.010	0.340	0.185
Chloride	1.000	120.0	27.143	14	0.900	180.00	33.225
Cyanide	0.010	0.02	0.013	4	0.005	0.020	0.011

^a Value in pH units

Note: Significant figures as reported in reference.

Table 7. CHEMICAL CHARACTERISTICS OF SETTLING-POND
DISCHARGE AT ONE MINE

Parameter	Average mine-discharge concentration, mg/l	Average settling-pond discharge concentration, mg/l
pH	7.9 ^a	8.0 ^a
TSS ^b	6	8.5
TDS ^c	243	291
COD ^d	4.5	15
Oil and grease	<5	<5
Total Iron	-	-
Dissolved Iron	<0.1	<0.1
Manganese	<0.1	<0.1
Sulfate	-	-

^a Value in pH units.

^b Total suspended solids

^c Total dissolved solids

^d Chemical Oxygen demand

ORE PREPARATION

PROCESS NO. 2

Preliminary Ore Preparation

1. Function - In order to increase the iron content, some of the mined ores are first screened, washed and crushed, then blended. The undersized material from the scalping screens having high moisture content are dried before shipment or, in some cases, sintered at the mine. Crushing frees most of the siliceous material from ore, screening removes coarse iron-poor rock, and blending produces a uniform product from iron ores of different characteristics and compositions by methods known as stacking and reclaiming. The blended material is transported by a belt conveyor to a screening station and then shipped, if at the mine or at the plant, for usage at the mine or at the plant.

At some plants treating magnetic taconite ore from the Mesabi Range, the mine run ore containing a small amount of fines and a heavy proportion of large blocks is brought in and dumped from high-capacity trucks directly into the top of a crusher installed at the mine site. The crushed material is conveyed to a surge pile, from which it is hauled by rail to concentrating plants.²

2. Input Materials - Mined ore.

3. Operating Parameters - Ambient.

4. Utilities - Electricity, water and fuel. Grinding of hard taconite requires about 8 kWh of power per gross ton* of primary feed (See Process 5).

5. Waste Streams - Dust emissions from crushing and blending operations amount to about 1 kilogram per ton of ore and have essentially the same composition as the ore being treated.³ Dust emissions contain ferrous or ferric oxide, some silica, and limestone. Other fugitive dust emissions come from transportation (conveyors, etc.) transfer points, storage, reclaim and screening.

In crushing of taconite ores, 15 to 20 percent of the primary crusher feed is eliminated and dumped.

6. EPA Source Classification Code - None exists.

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Ore Concentration

1. Function - The quality of iron ores is further improved by concentration by one of five methods:¹ washing, jigging, heavy-media separation, magnetic separation (physical operations), and flotation (chemical process). Washing separates the iron-bearing minerals from gangue materials by techniques based on differences in specific gravity. Jigging involves the stratification of ore particles and gangue by subjecting the crude ore to alternating upward and downward pulsations of water. The gangue overflows the jig, while ore particles are removed as an underflow product. The methods selected are based on physical and chemical properties of crude ore. In heavy-media methods, separation is achieved by suspending ore materials in a liquid having an intermediate specific gravity, in which the heavier iron mineral will sink and the lighter gangue will float to the surface. Magnetic separation is mainly used with taconite ores to separate magnetic valuables from nonmagnetic materials. Flotation techniques are effective in the separation of fine particles of iron minerals and gangue produced by grinding iron ore.¹ Various frothing and modifier agents are used to aid in the separation.² At present only three iron ore flotation plants exist in the United States. Flotation methods include:²

Anionic flotation of specular hematites

Upgrading of natural magnetite concentrates by cationic flotation

Upgrading of artificial magnetite concentrates by cationic flotation

Cationic flotation of crude magnetites

Anionic flotation of silica from natural hematites

Cationic flotation of silica from nonmagnetic iron formation.

The concentrate is conveyed on belt conveyors to storage facilities.

2. Input Materials - At Republic Mine, located on the Marquette Iron Range, the beneficiation plants process roughly 20,000 tons* of low-grade hematite per day to produce about 10,000 tons* per day of concentrated ore, containing 60 to 65 percent iron. Table 8 gives typical reagents and their quantities used for flotation of iron ore.²

* Metric tons (1000 kg).

Table 8. REAGENTS USED FOR FLOTATION OF IRON ORES

Type of flotation agent	Quantity, kg/ton* of iron ore processed
1. <u>Anionic flotation of iron oxides</u> (from crude ore)	
Petroleum sulfonate	0.5
Low rosin, tall oil fatty acid	0.25
Sulfuric acid	1.25
No. 2 fuel oil	0.15
Sodium silicate	0.5
2. <u>Cationic flotation of hematite</u> (from crude ore)	
Rosin amine acetate	0.2
Sulfuric acid	0.15
Sodium fluoride	0.15
Plant also includes phosphate flotation and pyrite flotation steps. Phosphate flotation employs sodium hydroxide, tall oil fatty acid, fuel oil and sodium silicate. Pyrite flotation employs xanthate collector	
3. <u>Cationic flotation of silica</u> (from crude ore)	
Amine	0.15
Gum or starch (tapioca flour)	0.5
Methylisobutyl carbinol	As required
4. <u>Cationic flotation of silica</u> (from magnetite concentrate)	
Amine	5.0 grams/ton
Methylisobutyl carbinol	As required

* Metric ton (1000 kg).

3. Operating Parameters - These concentration processes are usually carried out at ambient conditions.
4. Utilities - Producing 1 ton* of concentrate from 4 tons* of crude ore can require from 2000 to 20,000 liters of water, depending on the process. Upon leaving the process this water can serve to transport the waste materials to the tailings' basins.³ Data on energy consumption in mining and concentration processes are fragmentary and not well-defined (See Process 5).
5. Waste Streams - A total of 55 million tons* of tailings is produced from more than 100 million tons* of crude taconite mined annually. The daily release of tailings from some mines is: 57,400 tons* at Reserve Mining, 61,400 tons* at Erie Mining, and 11,500 tons* at Eveleth Taconite Co. (see Table C-3). The composition of the tailings varies with ore seam and the beneficiation processes. Detailed composition and particle size of tailings from Reserve Mining's plant at Silver Bay, Minnesota are given in Table 9 and Table 10, respectively.⁴ Tailings contain both coarse and fine particles.⁴

The tailings can cause some fugitive dust emissions. Drying of ore fines before beneficiation also creates air pollution problems. Other fugitive dust emissions come from conveyors, transfer points, storage, reclaim and screening. Slurry containing gangue materials and frothing agents from flotation operations which could present serious pollution problems, is usually sent to waste water ponds.

According to one report,⁵ iron ore mining and concentration adds little to the process water other than hardness. In some plants, where a heavy medium of finely divided ferrosilicon is involved, a slight solubility of iron in plant water may result. Generally, however, clarified water from the iron mining industry can be discharged into public waters.

The tailings wastewater from low-grade ore concentration contains about 70,000 to 500,000 milligrams per liter of suspended solids (98 percent of which settles rapidly). Large volumes of solids are deposited, roughly equivalent to three-fourths of the volume of ore mined. Table E-4 gives the analysis of wastewater discharge from iron ore beneficiation

* Metric ton (1000 kg).

Table 9. TYPICAL ANALYSIS OF TAILINGS

Composition	Percent
Iron	14.93
Silicon	33.03
Aluminum	0.35
Calcium	1.67
Magnesium	2.55
Manganese	0.37
Titanium	0.030
Phosphorus	0.026
Sodium	0.20
Potassium	0.08
Sulfur	0.03
Lead	0.005
Zinc	0.004
Nickel	0.002
Copper	0.004
Molybdenum	<0.001
Vanadium	<0.001
Cobalt	0.002
Chromium	0.004
Cadmium	0.0003
Carbon	0.11
Hydrogen	0.10
Oxygen	46.40

Table 10. TYPICAL PARTICLE SIZE ANALYSIS OF TACONITE TAILINGS^a

Size, microns	Percent
6,730	96.7
4,760	90.4
3,360	81.6
2,380	72.8
1,680	66.3
1,190	61.6
841	57.5
595	55.5
420	53.6
297	51.9
210	49.6
149	45.9
105	41.7
74	38.0
53	34.7
45	32.5
30	24.7
20	18.4
10	9.3
5	5.3

^a From the plant referred to in Table 10.

involving milling, flotation, and agglomeration at one mill. Asbestos like fibers found in the drinking water supply in Duluth, Minnesota, are believed to be due to the wastewater from taconite ore mining and concentration processes. Table E-5 shows the sources of mill wastewater from concentrating low-grade ore at Reserve mine.³

In a typical practice the tailings are sent to the pond where coarse tailings are removed and treated in a hydroseparator and a thickener. Overflow from the thickener may be pumped back to the concentrating plant. Two generally practiced tailings' disposal methods are: 1) ponding with eventual reclamation of the tailings pond, and 2) direct disposal into Lake Superior (used solely by Reserve Mining).⁵

6. EPA Source Classification Code - None exists.

7. References -

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Sintering

1. Function - The fine iron particles whether in natural or in concentrated ores are agglomerated to a size suitable for blast furnace charging. Sintering and pelletizing are by far the most common agglomeration methods. The sintering process converts materials such as fine ore concentrates, blast furnace flue dust, mill scale, turnings, coke fines, limestone fines, and miscellaneous fines into an agglomerated product that is suitable for blast furnace feed material. Some water may be added in preparing the agglomerate mix. The mixture is deposited on a traveling grate that conveys a bed of ore fines, or other finely divided iron-bearing materials, mixed with finely divided coke breeze and fluxes. Combustion air is drawn in, and the mixture is ignited by natural gas or fuel oil. It burns and forms a fused mass, which is fed to a cooler, crushed and screened.¹ The sinter production rate, which depends on the chemical and physical characteristics of the raw materials as well as control exercised in the sinter process, ranges from 0.002 to 0.0043 ton* per square centimeter (2.00 to 4.00 net tons per square foot) of grate area per 24 hours.² Table B-1, Appendix B presents average composition of sinter produced in 1968.

2. Input Materials - Table 11 lists the constituents of the strand burden required to produce 1 ton* of sinter.³

3. Operating Parameters - Combustion is maintained at a temperature of about 1300 to 1500°C.¹

4. Utilities - Electricity, water and fuel (gas or oil).

5. Waste Streams - The sintering process is a source of significant atmospheric emissions. Particulate emissions are estimated to be about 11 kilograms per ton* of sinter.⁴ Table 12 presents particle size data of particulate emissions.⁵

Total vented gases released during sintering amount to approximately 1.56 to 2.08 liters per second per kg/hour (1.5 to 2.0 scfm per lb/hour) of sinter. The gases generally leave the machine at a temperature of

*Metric tons (1000 kg)

Table 11. CONSTITUENTS OF THE STRAND BURDEN FOR A
TYPICAL SUPERFLUXED SINTER

Raw materials	Amount per 1000 kg of sinter product
Ore and reclaim	1,000 kg
Return fines	500 kg
Coke	50 kg
Flux	250 kg
Water	120 kg
Sinter (hearth layer)	250 kg
Air required	3100 m ³

Table 12. PARTICLE SIZE ANALYSIS OF PARTICULATE
EMISSIONS FROM A SINTERING MACHINE

Screen size, microns	Weight retained, percent	Cumulative weight, percent
5	25.1	25.1
10	47.6	72.7
20	14.6	87.3
30	5.8	93.1
44	5.0	98.1

200°C or lower. These gases are emitted from the windbox collection ducts and the bed of the grate. Emissions from the product cooler range from 0.21 to 1.26 liter per second per kg/hour (0.2 to 0.25 scfm per lb/hour) of sinter processed. Therefore, the total stack gas flow from sinter plants can be expected to range from 1.77 to 2.39 liters per second per kg/hour (1.7 to 2.3 scfm per lb/hour) of sinter production.⁶

The average particulate loading is 1.14 grams per cubic meter (0.50 grain/scf) of gas. Moisture content of gases ranges from 4.5 to 10 percent, depending on the quantity of water added during preparation of sinter mix.² The process emits not only sulfur oxides (about 30 to 40 percent of the sulfur in the charge is liberated), but also other volatile constituents. The sulfur content of gases could be as high as 2000 ppm. Hydrocarbon fumes may be evolved if oily scrap is used in preparation of sinter mix.²

In addition to sinter machines and sinter screens, all conveyor transfer points, loading points, chutes, and bins handling sinter are potential sources of fugitive dust. Many industries control the dust from these points by using a chemical wetting agent mixed with water.⁷ Electrostatic precipitators, baghouses and scrubbers are used to control emissions from sintering. A dry cyclone reduces the emissions to 1.0 kilogram per ton* of sinter; an electrostatic precipitator in series with a dry cyclone reduces emissions to 0.5 kilogram per ton* of sinter.*

6. EPA Source Classification Code - Sintering general - 3-03-008-03.

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2. Genton, R.G. Steel Mill Sinter Plant. (Presented at the 65th annual meeting of the Air Pollution Control Association, June 18-22, 1972.) p. 8.
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* Metric ton (1000 kg)

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Pelletizing

1. Function - Pelletizing is used primarily for agglomerating fine magnetic concentrations of taconite ores. The ore is ground, sized and mixed with water and binder, then rolled into small balls. A small amount of fine coal fuel may be added to the pellet mix. These "green" pellets are first dried then heated in a kiln to temperatures between 1200 and 1370°C to bind the small particles, and finally cooled. Control of moisture content of the pellets is very important to ensure strength. Normal moisture content runs between 10.0 and 10.25 percent. The pellets are conveyed through a weight meter to storage.¹ The three most important pelletizing systems are the traveling-grate (updraft and/or downdraft) system, the shaft furnace system, and the grate kiln system.²
2. Input materials - Magnetite taconites are concentrated and agglomerated at several locations in Minnesota. Tables B-2 and B-3, Appendix B give a typical analysis of taconite concentrates charged to pelletizer and composition of pellets produced.
3. Operating Parameters - Temperatures of 1200 to 1370°C are maintained at atmospheric pressure.¹
4. Utilities - Electricity, water and fuel (gas or oil) are required. As an illustration on a magnetic taconite plant, the heat requirement for pelletizing is 137,400 kilocalories per metric ton of pellets;³ similar processing of hematite requires twice the kilocalories of magnetic taconite per metric ton of pellets.⁴ Added to these heat requirements 94 kWh of electric power per metric ton of pellets (80,900 kilocalories) is required for mining, crushing and concentrating.³ Table 13 gives the energy consumption (according to the process evaluation group of the U.S. Bureau of Mines) at a typical magnetic taconite plant.³

Table 13. ENERGY CONSUMPTION FOR PROCESSES AT A 2 MILLION
TPY MAGNETIC TACONITE PLANT^a

Process	Electric power, %	Energy consumption, % natural gas	Both
Mining	7	-	2
Crushing	7	-	3
Concentrating	67	-	26
Pelletizing	15	88	60
Overall utilities	4	12	9
Total	100	100	100
Percent of total energy	39	61	100

^a Total consumption, kilocalories/ton of pellets is 256,000

5. Waste Streams - Since the concentrates received at pelletizing plants are usually moist, dust emissions from handling are minimal problem. Pelletizing is usually done at the mine site. Particulate emissions are similar to those from sintering plants (Process 4). Table 14 shows the particle size distribution of uncontrolled emissions.⁵

Table 14. PARTICLE SIZE DISTRIBUTION

Percent weight	Size, microns
1	<2
4	2 - 10
15	10 - 30
5	30 - 50
75	>150

6. EPA Source Classification Code - None exists.

7. References -

1. Kirk-Othmer. Iron. In: Encyclopedia of Chemical Technology, Volume 12, New York, John Wiley & Sons, Inc., 1968.
2. Iron Ores. In: The Making, Shaping and Treating of Steel, Ninth Edition, McGannon, H.E. (ed.). Pittsburgh, Pennsylvania, U.S. Steel Company, 1971. p. 225-226.
3. Target: New Technology to Improve Economics of Iron Ore Beneficiation. Engineering and Mining Journal. 175:65-68, December 1974.
4. North American Iron Ore: Launching a Rescue Mission for a Steel Short Economy. The Editors, Engineering and Mining Journal. 83-85, November 1974.
5. Goldberg, A.J. A Survey of Emissions and Controls for Hazardous and Other Pollutants. Environmental Protection Agency, Washington, D.C. Publication Number R4-73-021. February 1973. p. 69-75.

Nodulizing

1. Function - In the nodulizing process ore fines are heated in an oil- or gas-fired rotary kiln. The material moves through the kiln and is agglomerated into lumps by rolling of the charge at temperatures near the fusion point of 1260 to 1370°C.¹ The ore balls form nodules, which are then discharged and cooled. Nodulizing has no commercial acceptance. (Although nodules appear satisfactory for open-hearth use, they are not acceptable as an agglomerate for good blast-furnace performance largely because of their nonuniform size and inferior reducibility.³)
2. Input materials - Nodulizing is not as sensitive to feed moisture and particle size as compared to pelletizing.² Table 15 gives the hourly input rates to nodulizing kiln (results of 1953 tests) at Extaca's nodulizing plant using magnetite ore.² Table B-4, Appendix B gives chemical analysis of nodulized product from Taconite concentrate.

Table 15. HOURLY INPUT AND OUTPUT RATES FROM
NODULIZING KILN AT EXTACA

Material	Quantity, tons*/hr
Average feed rate	48.2
Limestone content in feed	1.9
Coal consumed	2.9
Average nodule production rate	46.5

3. Operating Parameters - Table 16 gives typical operating statistics for nodulizing at the plant referred to in Table 15.²

* Metric tons (1000 kg)

Table 16. TYPICAL NODULIZING PROCESS
OPERATING TEMPERATURES, °C

Optimum nodulizing temperature	
High-silica ore	1260-1300
Low-silica ore	1345-1370
Magnetite	1260-1290
Temperature of nodules discharged from cooler	20-150

4. Utilities - Fuel consumption during nodulizing ranges from 0.56 to 1.1 million kilocalories per ton of product.³ Table 17 gives heat and power requirements for producing nodules. (The data in Tables 15, 16 and 17 are for the same plant).²

Table 17. NODULIZING ENERGY REQUIREMENTS, PER KILOGRAM OF NODULES

Fuel consumption, calories per kilogram of nodules:	
For low-silica ore	668,830
For magnetite	512,790
Power requirements, kWh per kilogram of nodules	0.018

5. Waste Streams - No data are available on emissions from nodulizing processes. The emissions should be lower than those from sintering (See Process 4).

6. EPA Source Classification Code - None exists.

7. References -

1. Kirk-Othmer. Iron. In: Encyclopedia of Chemical Technology, Volume 12, New York, John Wiley & Sons, Inc., 1968. p. 1-21.
2. Bennett, R.L., R.E. Hagen, and M.V. Mielke. Nodulizing Iron Ore and Concentrates at Extaca. Mining Engineering. 6:32-38, January 1954.
3. Iron Ores. In: The Making, Shaping and Treating of Steel, Ninth Edition. McGannon, H.E. (ed.). Pittsburgh, Pennsylvania, U.S. Steel Company, 1971. p. 226.

ORE PREPARATION

PROCESS NO. 7

Briquetting

1. Function - In the briquetting process, ore fines are mixed with a binder and formed into compact masses between two rotating rolls.¹ In hot-ore briquetting process, minus 1/4 inch hematite, ore fines are heated to between 870° and 1040°C, and then briquetted while hot in a double-roll briquetting press at loads of 45 to 55 tons.*²
2. Input Materials - Binder substances used are the same as in sintering for cold briquetting, whereas no binder is used in hot briquetting.
3. Operating Parameters - Temperatures in the process range from 650 to 980°C for cold briquetting.¹
4. Utilities - External heat is needed. Data on quantities and type of fuel are not available. Electricity is also required.
5. Waste Streams - Data are not available on emissions from briquetting. The emissions should be lower than those from the sintering process, because the mass of material is not heated to as high a temperature as in sintering.
6. EPA Source Classification - None exists.
7. References -
 1. Kirk-Othmer. Iron. In: Encyclopedia of Chemical Technology, Volume 12, New York, John Wiley & Sons, Inc., 1968. p. 1-21.
 2. Iron Ores. In: The Making, Shaping and Treating of Steel, Ninth Edition, McGannon, H.E. (ed.), Pittsburgh, Pennsylvania, U.S. Steel Company, 1971. p. 226-227.

* Metric Tons (1000 kg)

COKE PRODUCTION

Coke production is an integral part of major iron and steel operations. Coke is charged to the blast furnaces to provide the heat and carbon required for smelting and reducing the iron ore. Since approximately 466 kilograms of coke is required for every ton of iron produced in blast furnaces, the coke plants process thousands of tons of coal a day into coke and coke by-products. Coke is manufactured by the by-product method in enclosed slot-type ovens. The Beehive process is being phased out because the by-product method is much more efficient and produces less pollution.

Many iron and steel companies coke coal obtained from their own mines. In 1974, 91.6 percent of the coke used in the industry was produced at coke plants operated by iron and steel manufacturers. Table B-5, Appendix B presents data on coke and coal products produced in 1974 (See Table C-5, Appendix C, for production data on captive mines of the steel industry). Figure 2 shows the processes of the coke plant which are described in this section. These processes are:

8. Coal mining and transportation
9. Coal preparation
10. Charging of coke ovens
11. Coking
12. Pushing and quenching
13. Coke handling and tar condensation

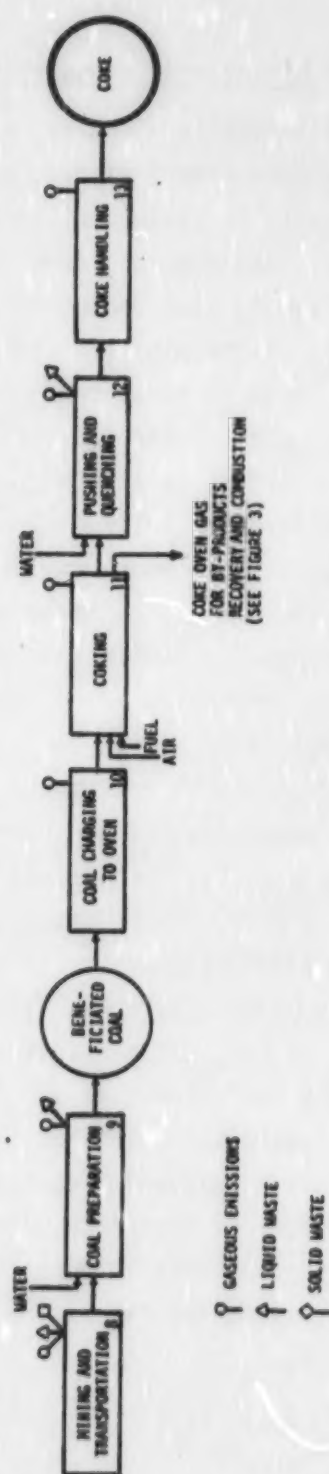


Figure 2. COKE PRODUCTION

Coal Mining and Transportation

1. Function - Coal is basically mined by three methods: 1) strip (surface) mining, 2) underground (deep) mining, and 3) auger mining. The methods are dictated mostly by geological conditions. Strip mining is generally practiced only when the coal seam lies close to the earth's surface. The two most widely used underground mining methods are room and pillar and longwall. Auger mining is relatively inexpensive and is reported to recover 60 to 65 percent of the coal in the part of the bed where it is used.¹ After mining the coal is broken into lumps suitable for hauling to the surface by electric locomotives, or in increasing number of mines, by conveyor belts. In most underground mines, low, flat loading machines gather the loose coal onto shuttle cars. In open-pit or surface mining, the coal is gathered up by large power shovels and is loaded usually on trucks for hauling to the cleaning plant or rail transportation.

The run of mine coal is delivered to the cleaning facilities where the coal is separated from coarse rock and slate by the use of a scalper or breaker or crusher, then screened and sized. Depending upon other impurities and cleaning desired, the coal is further treated by heavy media washing, diester tables, froth flotation and drying. The sized coal can be mixed for direct shipment or is stored in piles before being transported to the coke plant by trucks, rail or barge.

2. Input Materials - In 1974, iron and steel industry's blast furnaces consumed 81,420,000 tons* of bituminous and 403,000 tons* of anthracite coal.² In its natural state coal contains impurities such as sulfur, clay, rock slate, and other inorganic materials. Mining processes add more impurities in the form of mine rock, dirt, tramp iron, and wood.

3. Operating Parameters - Mining is done at ambient conditions.

4. Utilities - Energy is needed for mining equipment in the form of electricity, water and fuel.

* Metric tons (1000 kg)

5. Waste Streams - Among the major environmental problems in coal mines are methane in coal beds and coal dust in the atmosphere of mines; both present health and safety problems in mining operations. Open coal stockpiles exposed to the weather are responsible for significant dust emissions. Airborne coal dusts are hazardous in potential for explosion. Reclamation of strip mined lands, drainage of acid mine waters, coal cleaning, and solid waste disposal are other environmental problems.³ The nature of acid mine water varies from site to site. Several typical mine water analyses are listed in Table 18.⁴ Solid refuse from coal mining consists mainly of insoluble coal, bone, calcite, gypsum, clay, pyrite, or marcacite and overburden.⁵

6. EPA Classification Code - None exists.

7. References -

1. A Dictionary of Mining, Mineral, and Related Terms. Thrush, P.W. and Staff of Bureau of Mines. (ed.). U.S. Department of Interior, 1968.
2. Coke and Coal Chemicals in 1974 (Preliminary release of information pending publication of Bureau of Mines Minerals Yearbook), Mineral Industry Surveys, U.S. Department of Interior, Bureau of Mines. Washington, D.C. November 1975.
3. Hunter, T. W. Bituminous Coal and Lignite, Minerals Facts and Problems, Bureau of Mines. Washington, D.C., U.S. Government Printing Office, 1970.
4. Girard, L. "Operation Yellowboy." (Unpublished report prepared by Dorr Oliver, Inc., for the Coal Research Dept. of Mines and Minerals Industries, Commonwealth of Pennsylvania, 1965.)
5. Lucas, J. R. and D. R. Maneval. Plant Waste Contaminants. In: Coal Preparation. W. L. Midd Series, Leonar, J. W. and D. R. Mitchell. (eds.). New York, American Institute Mining, Metallurgical and Petroleum Engineers, Inc. 1968.

Table 18. CHEMICAL ANALYSES OF WATER AT DIFFERENT MINE SITES^a

Sample	A	B	C
pH, field	4.3	2.9	4.4
pH, Lab	3.20	2.65	3.65
Iron, ppm			
Total iron, field	486	828	17
ferrous lab	454	733	0.5
Total iron, lab	463	1348	1.3
Acidity, ppm CaCO ₃			
free	20	45	15
total	850	5820	86
Alkalinity, ppm CaCO ₃	0	0	0
Manganese, ppm	16	70	10
Silicon dioxide, ppm	35	81	4
Aluminum, ppm	24	595	13
Calcium, ppm	335	1263	89
Magnesium, ppm	0	16	0
Potassium, ppm	0	0	0
Sodium, ppm	4.0	2590	4.0
Chlorine, ppm	15	2010	36
Sulfate, ppm	1867	12838	301
Copper, ppm	0.3	0.7	0.2

^a Different samples from different locations.

Coal Preparation

1. Function - Preparation involves the breaking, screening, pulverizing, blending, and mixing of the coal. Incoming metallurgical coal from the mine is brought to a breaker building at the coke plant. The breaker is provided to remove the refuse from the coal and break up frozen lumps in winter. The coal is then screened. The coarse coal flows to a rotary crusher and final pulverizing is done in the fine-coal system. Low-and high-volatile coals are pulverized separately, and coals of different volatilities are usually blended to improve the chemical and physical properties of the coke and to control the pressure on the oven walls developed during carbonization. To further increase the uniformity and quality of coals to be fed to coke ovens, their bulk density is controlled. If the bulk density of the coal is below specification, oil is added; if the bulk density of the coal is above specification, water is added. The coals are then conveyed to coke oven battery coal-storage bins.

2. Input Materials - Bituminous coals of high-volatile coal is usually blended with either or both medium- and low-volatile coals to provide charge for the coke ovens. Coals of low ash content, low sulfur content, and suitable coking properties are used. A major portion of the pulverized and blended coal (typically 70 percent) is in particles smaller than 0.49 centimeter.¹

Table 19 gives an analysis of typical coke to be charged to an oven.²

Table 19. ANALYSIS OF A TYPICAL COKE OVEN CHARGE, DRY BASIS

Constituents	%
Water	4.0
Volatile matter	31.4
Fixed carbon	63.4
Ash	5.2
Sulfur	0.76
Phosphorus	0.008

Open stockpiles of coal may reach a height of 30 meters and cover up to 500 thousand sq meters.³

3. Operating Parameters - Coal preparation operations are carried out at ambient conditions.

4. Utilities - Electrical power is needed for coal preparation equipment.

5. Waste Streams - Coal dust is emitted from crushing, screening, storage, reclaiming, conveying, and bin loading operations. Particulate emissions increase as surface moisture in the coal decreases. Emissions are on the order of 5 kilograms per year per ton* of material stored. Particle sizes released to the air average well below 0.1 millimeter, and suspended fractions are in the range of 1 to 10 microns.⁴

About 2 to 5 grams of coal are lost for every kilogram of coal received (dry basis). Much of this loss occurs by rainout of fines from storage piles and by wind during outdoor handling and storage. About 20 percent of the total loss of coal occurs as dust from the pulverizing and blending operations.³ The solids concentration in plant waters usually ranges between 30 and 110 grams per liter but may reach 200 grams. Fine coal and mineral particles such as clays remain suspended in most plant waters. These particles vary in size from 28-mesh to colloidal dimensions; most can be eliminated by thickeners, cyclones, and filters.⁴ Some of the trace elements contained in the emissions are beryllium, selenium, arsenic, lead, cadmium, strontium, titanium, potassium, and sulfur.⁵

6. EPA Source Classification -

Coal crushing and handling - 3-03-003-07.

7. References -

1. Manufacturing of Metallurgical Coke and Recovery of Coal Chemicals. In: The Making, Shaping and Treating of Steel, Ninth Edition, McGannon, H.E. (ed.). Pittsburgh, Pennsylvania, U.S. Steel Company, 1971. p. 104-116.
2. Kirk-Othmer. Carbonization. In: Encyclopedia of Chemical Technology, Volume 4. John Wiley and Sons, Inc., New York. 1968.

* Metric ton (1000 kg)

3. Varga, J. Jr., and H. W. Lownie. Sources of Air Pollution In: Final Technological Report on A Systems Analysis Study of the Integrated Iron and Steel Industry. Battelle Memorial Institute, Columbus, Ohio. May 1969.
4. Barnes, T. M., A. O. Hoffman, and H. W. Lownie. Evaluation of Process Alternatives to Improve Control of Air Pollution from Production of Coke. Battelle Memorial Institute. Columbus, Ohio, January 31, 1970.
5. 1974, Keystone Coal Industry Manual. New York, Mining Information Services of The McGraw Hill Publications, 1974.

Charging of Coke Ovens

1. Function - Prepared coals are carried from the coke-oven battery coal-storage bins to the coke ovens in larry cars with three to five hoppers matching the openings for coal charging in each oven. All modern by-product coke ovens are designed to take a definite volume of coal per charge. Two types of larry cars are used: the gravity discharge larry, and the mechanically unloaded larry.¹ Charging is accomplished through openings in the top of the coke oven. To prevent escape of the gases from the oven during charging, gas-cleaning devices (mechanical or venturi scrubbers) have been installed on the larry cars. A steam-jet aspirator is used in most plants to draw gases from the space above the charged coal into a gas collecting main.¹ Some newer batteries use pipeline charging, for preheated coal.
2. Input Materials - A specified volume of coal, typically 16 to 20 tons,* is charged to the oven for each coking operation. Bethlehem Steel Corporation, Burns Harbor, Indiana, has a charging capacity of 39.4 cu. meter (1,391 cu. ft. or approximately 35 tons) per oven.²
3. Operating Parameters - Prepared coal is charged at ambient conditions.
4. Utilities - Energy is needed for material transportation and for preheating when done. Quantitative data is not available.
5. Waste Streams - The analytical properties of the coal have no apparent significance on the quantities of emission during charging.³ Dust is evolved when the larry car is filled with coal and weighed. Charging the coal to ovens results in some smoke. Under the conditions of charging some of the hydrocarbons contained in coal are directly volatilized (anthracene, phenanthrene, and naphthalene). Some coals break down to yield methane and lighter aromatic compound such as benzene. Some emit hydrogen and are rapidly coked to graphite. Small, porous globules of coke carbon (coke ball) are sometimes emitted in the charging gases. The

* Metric ton (1000 kg)

gases contain some nitrogen, carbon monoxide, carbon dioxide, hydrogen, methane, and steam.⁴ Charging coal into the oven accounts for 60 to 70 percent of total emissions from oven batteries. Unsubstituted polynuclear aromatics constitute up to 3 percent of the collected volatiles or 4 to 6 percent of the benzene-soluble portion of the collected volatiles emitted during the charging operation.⁵

Table 20 gives the conditions to which larry car operators are exposed inside the operator's cab³ and this provides an indication of pollutant concentrations in this area.

Currently, the following methods are in use for the reduction of charging smoke: 1) external collection and cleaning of gases from the larry car, 2) collection of gases in a gas collecting system, with standard larry car charging, 3) "staggered" charging which consists of charging each oven port separately under negative pressure, and 4) pipe line charging.

Table 20. TIME-WEIGHTED AVERAGE CONCENTRATIONS OF GASES INSIDE THE LARRY CAR (BASED ON 8-HOUR WORK DAY)

Substance	Quantity
Coal tar pitch	0.2 mg/m ³
SO ₂	5.0 ppm
H ₂ S	10.0 ppm
CO	50.0 ppm

Emissions from oven charging contain on the order of 0.75 kilogram particulate, 0.02 kilogram SO₂, 0.6 kilogram carbon monoxide, 2.5 kilogram hydrocarbons, 0.03 kilogram NO_x and 0.02 kilogram ammonia, per ton coal charged.⁶

6. EPA Source Classification Code - 3-03-003-02.

7. References -

1. Manufacture of Metallurgical Coke and Recovery of Coal Chemicals. In: The Making, Shaping, and Treating of Steel, Ninth Edition, McGannon, H.E. (ed.). Pittsburgh, Pennsylvania, U.S. Steel Company, 1971. p. 118-128.

2. Coal and Coke. In: Watkins Cyclopedia of the Steel Industry, Twelfth Edition. Pittsburgh, Pennsylvania, Steel Publication, Inc. 1969. p. 46.
3. Stoltz, J. H. Coke Charging Pollution Control Demonstration. Environmental Protection Agency, Contract No. CPA 70-162. March 1974.
4. Barnes, T. M., A. O. Hoffman, and H. W. Lownie. A Final Report on Evaluation of Process Alternatives to Improve Control of Air Pollution From Production of Coke. Battelle Memorial Institute, Columbus, Ohio. May 1969.
5. Smith, W. M. Evaluation of Coke Oven Emissions. Air Pollution Control Association. (Presented at the Annual Meeting, 63rd, St. Louis, Mo. June 14-18, 1970.)
6. Iron and Steel Mills. In: Compilation of Air Pollution Emission Factors. Environmental Protection Agency, Research Triangle Park, N.C. Contract Number CPA-22-69-119. April 1973.

Coking

1. Function¹ - Coke is the residue of destructive distillation of coal. Coal is heated in the coke ovens (with no air in the oven) by adjacent chambers or flues using: 1) some of the gas recovered from the coking operation, 2) cleaned blast-furnace gas, or 3) a mixture of coke-oven and blast-furnace gases. The reduction starts at the side walls and continues toward the center, when it reaches the center all the coal in the oven is converted to coke. The end doors are opened and a ram then pushes the incandescent coke out of the oven through a coke guide and into the quenching car. The oven is generally left open for several minutes to burn off the carbon collected on the roof around the charging holes. A typical coke oven is 9.1 to 13.1 meters long, 1.8 to 4.3 meters high, and 28 to 56 centimeters wide. Some newer units are 15.2 meters long and 6.6 meters high and 46 centimeters wide. The coke oven operates with a coke conversion factor of approximately 70 percent depending upon the type of coal carbonized, carbonization, temperature and method of coal-chemical recovery. The newer ovens have capacities of 34 tons or more of coal per oven. Coke ovens are constructed in groups and called batteries. At some plants, a battery contains more than 100 ovens. Coking time requires approximately 17 hours but newer refractory techniques are permitting coking to take place in 14.5 hours or less.

During carbonization, about 20 to 35 percent by weight of the initial charge of coal is evolved as mixed gases and vapors. The gas containing volatile matter sent to the collecting main through an opening at the top of the oven. Table 21 gives the coke and coke chemical yields from one net ton* of coking coal.¹

2. Input Materials - Feed to the coke oven is prepared coal and combustion gas. Approximately 35 percent of the coal gas produced is returned to the oven.

3. Operating Parameters - Carbonization temperature is about 1150°C.²

* Metric tons (1000 kg)

Table 21. TYPICAL YIELDS FROM ONE TON OF COKING COAL

Blast-furnace coke	544 - 634 kg
Coke breeze	45 - 91 kg
Coke-oven gas	270 - 325 m ³
Tar	30 - 45 liters
Ammonium sulphate	9 - 13kg
Ammonia liquor	57 - 132 liters
Light oil	9 - 15 liters

Heat input to the coke oven at a temperature of 1350°C is 690,000 kcal/ton (2,780,000 Btu/ton) of coal. Stack and radiation losses are 131,000 kcal/ton (527,000 Btu/ton) of coal, i.e. 19 percent losses.³

4. Utilities - Overall heat requirement for coal carbonization amounts to 560 to 640 kcal/kg (1000 to 1150 Btu's per pound) of coal.²

5. Waste Streams - Emissions of gas and dust are released; 1) when the oven ports are opened to charge the coal (Process 10), 2) during the coking by leakage through doors and ports, and 3) when the hot coke is pushed from the oven (Process 12).

Several investigators report the presence of suspected carcinogenic hydrocarbons (i.e. polycyclic or polynuclear aromatic hydrocarbons) in coke oven smoke. Prominent among these is benzo(a)pyrene.⁴

Table 22 gives emission factors for coking and coke oven pushing or discharging.⁵ A complete list of chemicals present in coke oven off-gases is given in Table E-6, Appendix E.

6. EPA Source Classification Code - 3-03-003-03 - oven pushing.

7. References -

1. Manufacture of Metallurgical Coke and Recovery of Coal Chemicals. In: The Making, Shaping and Treating of Steel, Ninth Edition, McGannon, H.E. (ed.). Pittsburgh, Pennsylvania. U.S. Steel Company. 1971. p. 105-177.
2. Kirk-Othmer. Carbonization. In: Encyclopedia of Chemical Technology, Volume 4, Wiley and Sons, Inc., New York, 1966. p. 400-423.
3. Roland Kemmetmueller, Pres. American Wagner - Biro Co., Inc. Pittsburgh, Pennsylvania, Iron and Steel Engineer. October 1973.
4. Boyland, E. Polycyclic Hydrocarbons, British Medical Bulletin, 202, 1964.
5. Iron and Steel Mills, In: Compilation of Air Pollution Emission Factors, Environmental Protection Agency, Research Triangle Park, N.C. Contract Number. CPA-22-69-119. April 1973.

Table 22. EMISSION FACTORS FOR COKING AND COKE OVEN PUSHING

Pollutant	Coking cycle	Discharging
	(kg/ton * of coal charged)	
Particulate	0.05	0.3
CO	0.3	0.035
HC ^a	0.75	0.1
NO ₂	0.005	
Ammonia	0.03	0.05

^a Expressed as methane.

* Metric ton (1000 kg)

Pushing and Quenching

1. Function¹ - Red-hot coke from the oven is pushed into a quenching car and taken to a quenching station, where a water spray system of water cools the coke. Although a dry quenching method is available, and is used exclusively in Russia, all but one or two plants in the U.S. use wet quenching principally for economic and operating reasons. The usual practice is to achieve an average moisture content of 2 1/2 percent in the metallurgical coke after screening.
2. Input Materials - All the coke product from coke ovens is quenched.
3. Operating Parameters - Ambient conditions are maintained.
4. Utilities - Approximately 15 to 20 percent of quench spray water is evaporated in quenching and increasing the moisture content of the quench coke, and the remainder recirculated.² The amount of water for evaporation and moisture content to the coke is about 500 liters per ton*.³ Electricity is used by pumps and transferring equipment.
5. Waste Streams - Pushing emissions vary with the degree of coking. Well-coked coal will smoke very little when pushed into the quench car, while poorly coked "green" coke will cause excessive smoke. Particulate emissions for pushing operations were presented in Table 22 and amount to about 0.3 kg/ton of coal charged.⁴ At one plant 21.5 percent of the particulate from pushing operations was larger than 74 microns. The distribution of those particle less than 13.5 microns in size is shown in Table 23.⁵

Baffles have been installed near the top of some quenching station stacks to minimize carryover of entrained dust and water droplets out of the top of the stacks by the steam generated in quenching. Most of the solids, in the form of coke breeze, are either used within the plant or sold. Table 24 gives a screen analysis of the particulates generated at the quench of one coke plant.⁶ Table 25 gives an average analysis of quench water samples.⁷ The average weight of particulates emitted during a 2-minute quench cycle at one plant was calculated to be 2.7 kilograms.

* Metric ton (1000 kg)

Table 23. PARTICLE SIZE DISTRIBUTION FOR COKE OVEN EMISSION
SAMPLE DURING TYPICAL PUSH AT MAJOR NORTHWEST INDIANA STEEL CO.

Size, microns	% by weight of total sample collected on plates
13.5	31.3
8.6	27.7
5.6	12.3
4.0	9.1
2.5	7.3
1.3	7.3
0.8	3.8
0.5	1.0

These emissions could be reduced to less than 0.4 kilogram by installation of baffles.⁶

The volume of the contaminated wastewater averages about 335 to 335 liters per ton of coke. Analysis of coke wash water at one plant showed that the suspended solids exceeded 350 ppm and chloroform-extractable materials exceeded 260 ppm.⁸ Table E-7, Appendix E, gives a complete list of chemicals potentially present in the emissions from quenching and direct cooling.

6. EPA Source Classification Code - 3-03-003-04.

7. References -

1. Manufacture of Metallurgical Coke and Recovery of Coal Chemicals. In: The Making, Shaping and Treating of Steel. Ninth Edition, McGannon, H.E. (ed.). Pittsburgh, Pennsylvania, U.S. Steel Company, 1971. p. 130.
2. Ess, T.J. The Modern Coke Plant. Iron and Steel Engineer. C3-C36. January 1948.
3. Gollmar, H.A. Coke and Gas Industry. Industrial Engineering Chemistry. 39:596-601. 1947.
4. Iron and Steel Mills, In: Compilation of Air Pollution Emission Factors, Environmental Protection Agency, Research Triangle Park, N.C. Contract Number, CPA-22-69-119. April 1973.

Table 24. SCREEN ANALYSIS OF QUENCH-TOWER PARTICULATES

Screen size		Weight percent	
Mesh	Microns	Retained	Cumulative
6	3327	0	0
16	1167	1	1
30	589	9	10
50	298	35	45
100	147	39	84
200	74	13	97
-200	-74	3	100

Table 25. AVERAGE ANALYSIS OF QUENCH WATER SAMPLES

Contaminants	Concentration, ppm
Phenols	776
Sulfates	1066
Chlorides	1954
Total ammonia	2517
Cyanides	98
Total solids	5214

5. Yost, K.J., et al. Purdue University. The Environmental Flow of Cadmium and Other Trace Elements: Volume 1. National Science Foundation. PB-229478. June 30, 1973.
6. Barnes, T. M., A. O. Hoffman, and H. W. Lownie. A Final Report on Evaluation of Process Alternatives to Improve Control of Air Pollution from Production of Coke. Battelle Memorial Institute, Columbus, Ohio. May 1969.
7. Results of analysis of a series of quench water samples by 1) Allegheny County Bureau of Air Pollution Control, 2) U.S. Steel Clairton works, 3) Pennsylvania Department of Health - Division of Sanitary Engineering, 4) The University of Pittsburgh - Department of Occupational Health.
8. Kozar, R. S. Environmental Pollution Control. Blast Furnace and Steel Plant. 598, August 1970.

Coke Handling

1. Function - The quench car brings the quenched coke to the coke warf, where it is dumped in a thin layer for drying and for detection of unquenched coke (by visual inspection). Unquenched coke is sprayed with water. When cool, the coke is fed onto a conveyor belt and transferred to a screening station for separation into sizes.¹ Tables B-6 and B-7, Appendix B give typical sizes and properties of coke produced in the screening and separation step.
2. Input Materials - Quenched coke is fed to the coke wharf, and conveyed to crushers, and then to storage.
3. Operating Parameters - Coke is cooled under ambient conditions.
4. Utilities - Electricity for the quench car, conveyor drives, crushers and screens. Water for additional quenching is used as required.
5. Waste Streams - Coke dust may be released at the transfer points or in mechanical operations such as screening. Size of particulates released to air is well below 0.1 millimeter, and the suspended fractions are in the range of 1 to 10 microns. Coke handling losses are typically less than 0.01 percent.²
6. EPA Source Classification Code - None exists.
7. References -
 1. Manufacture of Metallic Coke and Recovery of Coal Chemicals. In: The Making, Shaping, and Treating of Steel, Ninth Edition, McGannon, H.E. (ed.). Pittsburgh, Pennsylvania, 1971. p. 133-134.
 2. Barnes, T.M., A.O. Hoffman, and H.W. Lownie. A Final Report on Evaluation of Process Alternatives to Improve Control of Air Pollution from Production of Coke. Battelle Memorial Institute, Columbus, Ohio. May 1969.

COKE BY-PRODUCTS RECOVERY

Although most coke-oven plants in the United States are equipped to process tar and light oil, the extent to which an individual plant produces the various products depends upon economic conditions and size of the plant.

Figure 3 shows the coke by-products recovery segments. The processes described in the following section are:

- Primary cooling/reheating

- Tar decanting

- Recovery of phenol

- Distillation of ammonia

- Ammonia absorption

- Crystallization and filter drying

- Light oil recovery

- Fractionation and refining of light oils

Table B-8, Appendix B, presents yields and analysis of products of coking and recovery processes.

Primary Cooling/Reheating

1. Function - The hot gases resulting from carbonization leave the coke oven through a standpipe into a collecting main. The gases and vapors are sprayed with weak liquor (flushing liquor) to reduce the temperature and volume. As a result of this cooling, most of the tar is condensed and is decanted along with the unevaporated flushing liquor into an adjacent tank.¹

The coke oven gas and uncondensed vapors are passed from the collecting main to either a direct or indirect primary cooler for further cooling. As the gas cools, tar and ammonia liquor are condensed. This mixture of condensed liquor flows to the decanter (Process 15). The gas, with a small amount of resulting tar fog, then passes through a steam-driven centrifugal gas exhauster, which removes some of the remaining tar fog and passes the gas to an electrostatic precipitator. In the precipitator, the final traces of tar are removed. The gas is treated in a reheater where its temperature is raised and then passes through an ammonia scrubber (Process 18). The collected tar is added to the decanter (Process 15).

Depending on the sulfur content of the coal used in the ovens, the coke oven gas may contain 9 to 17 grams hydrogen sulfide per cubic meter. Some plants partially or completely strip the sulfur compounds from the coke gas.²

2. Input Materials - The gas formed in coking may be used as fuel or further treated. The quantities treated in primary coolers depend on the demand for by-products. The input gas analysis to the cooler is about 50 percent hydrogen, 27 percent methane and the remaining 23 percent ethane, benzene, CO₂, CO, O₂ and N₂.¹

3. Operating Parameters - A slightly reduced pressure is maintained in the collecting main to prevent loss of the gases. The weak ammonia spray reduces the temperature of gas from 600°C to about 100°C.¹ The temperature of the gases is dropped to 30°C in the cooler and raised to 60°C in the reheater. Pressure varies from 30 cm. water below atmospheric pres-

sure to a discharge pressure of 1.8 kilograms per square centimeter.³ A precipitator is placed either before or after the exhauster to collect condensed organic droplets.

4. Utilities - The heat transferred from the hot gases to the cold liquor is recovered by indirect heat exchange with circulating water. Energy is required for operating the exhauster, electrostatic precipitator and reheater.

5. Waste Streams - Some particulate is evolved through leaks in the equipment.

6. EPA Source Classification Code - None exists.

7. References -

1. Kirk-Othmer. Carbonization. In: Encyclopedia of Chemical Technology, Volume 4, New York, Wiley & Sons, Inc., 1968. p. 400-423.
2. Gollmar, H.A. Coke and Gas Industry. Industrial Engineering Chemistry. 39:596-601. 1947.
3. Griswold, J. Chemical Engineering Series, Fuels, Combustion, and Furnaces. McGraw Hill Book Company, Inc. 1946.

Tar Decanting

1. Function - The tar condensed in the collecting main is decanted along with the unevaporated flushing liquor into an adjacent tank where tar settles to the bottom and leaves through a valve into the tar decanter. The flushing liquor is passed to settling tanks. The ammonia liquor condensed in the primary coolers, together with the tar removed by the exhauster and precipitator, is also added to the tar decanter where the tar is separated from the weak ammonia liquor by decantation. Part of weak ammonia liquor is pumped back to the collecting main sprays, another part is passed to the cooling coils of the primary cooler, and the remainder is sent to an ammonia still. From the crude tar collector in the decanter, pitch sludge settles to the bottom and is mechanically raked out for disposal, usually by burning as fuel. Settled crude tar is sent to a separate plant for secondary processing by distillation, where naphthalene is obtained as the main product.

The yields of tar vary among plants with the kind of coals carbonized and the carbonizing temperatures. The yield in 1972 averaged 45 kilograms of tar per ton of coal. Generally from 4 to 5 percent by weight of the coal carbonized is recovered as tar. The relative quantities of tar tapped depend upon a number of economic factors, such as availability and current market for tar and tar distillate. Crude tar contains a large number of chemical compounds. One source includes 348 compounds that have been identified in tar. Some of the large plants recover a number of tar derivatives, including creosote oil, cresylic acid, cresols, naphthalene, phenol, pyridine, and medium and hard pitch.¹ Table B- 9, Appendix B, presents the composition of coke oven tar.

2. Input Materials - Weak ammonia liquor and condensed tar from the collecting main, the exhauster, and the precipitator are the feed to the decanter. The input liquor contains from 1 to 5 grams suspended solids and dissolved tarry compounds including phenols and tar acids (expressed as phenols) per liter.²

3. Operating Parameters - Ambient.
4. Utilities - None required.
5. Waste Stream - Pitch sludge is a waste stream if not burned as fuel. There is some odor at the decanter. Ammonia and organic fumes are strong at the sumps where decanted liquor and other flush liquor is collected for recycling to the collecting main sprays.³
6. EPA Source Classification Code - None exists.
7. References -
 1. Sheridan, E. T. Coke and Coal Chemicals. In: Minerals Yearbook, Volume I and II. Bureau of Mines, Washington, D.C., U.S. Government Printing Office, 1972.
 2. Ammonia and Ammonium Salts, Chapter 10. In: Coal, Coke, and Coal Chemicals, Chemical Engineering Series, New York, McGraw-Hill Co., Inc., 1950. p. 309.
 3. Varga, J. Jr., and H. W. Lownie. Final Technological Report on A Systems Analysis Study of the Integrated Iron and Steel Industry. Battelle Memorial Institute, Columbus, Ohio. May 1969.

Phenol Recovery

1. Function - Two processes are available to recover phenol, the vapor-recirculation process and the solvent extraction process. In the solvent extraction process weak ammonia liquor recovered with the volatile products of coal carbonization is contacted countercurrently in a scrubber with benzene or light oil to remove phenol (phenols are more soluble in benzene or light oil than in water). The weak ammonia liquor and light oil flows are maintained in the ratio of approximately 1.25 oil to 1.0 liquor.¹ The phenol-free liquor flows to a storage tank for further processing (Ammonia Still, Process 17). The phenolized benzene or light oil is washed with caustic soda in a tower. After a week or two, the caustic in the light oil caustic washer is saturated with sodium phenolate, which is drained into a carbolate concentrator. The sodium carbolate in the concentrator is boiled to remove entrained solvent and moisture. It is then neutralized with carbon dioxide to liberate crude phenols and phenol homologues.²

The vapor-recirculation method is operated in conjunction with the ammonia still. Ammonia is removed from the weak liquor in the "free leg" (See Ammonia Still, Process 17) of the ammonia still. So-called "free" ammonia and acidic gases (H_2S , CO_2 and HCN) and a minimum amount of phenol are removed in this step. The ammonia liquor leaving the base of the free leg is transferred to the dephenolizing unit where phenols are removed by vaporization with steam followed by extraction with caustic soda. Phenols are recovered from the sodium phenolate solution. The dephenolized liquor is transferred to the "fixed" leg of the ammonia still.

2. Input Materials - Weak ammonia liquor, benzene or light oil, caustic soda and carbon dioxide or sulfuric acid are inputs to the solvent extraction process. In the vapor-recirculation process weak liquor from the free leg of the ammonia still is treated with steam and caustic soda. The input ammonia liquor contains 0.5 to 3.0 grams phenol per liter.² The pH of the liquor should be within a range of 6.5 to 9.0 for optimum

dephenolization.³ A phenol removal efficiency of 95 to 98 percent is achieved.

3. Operating Parameters - The solvent extraction process is carried at ambient conditions. The vapor-recirculation process is conducted at 100°C.

4. Utilities - Electricity is required for pumping.

5. Waste Stream - Particulate may be emitted. The scrubber and washer create some wastewater that must be treated.

6. EPA Source Classification Code - None exists.

7. References -

1. Carbone, W.E. Phenol Recovery From By-Product Coke Wastes. Sewage and Industrial Wastes. 22:200-205. February 1950.
2. Manufacture of Metallurgical Coke and Recovery of Coal Chemicals. In: The Making, Shaping and Treating of Steel, Ninth Edition, McGannon, H. E. (ed.). Pittsburgh, Pennsylvania. U.S. Steel Company, 1971.
3. Heller, A.N. et al. Some Factors in the Selection of Phenol Recovery Process. (Proceedings of Twelfth Industrial Waste Conference. Purdue University. May 14, 1957). p. 103-122.

Ammonia Still

1. Function - Ammonia is transferred to the vapor phase from aqueous solution by distillation and treatment with alkali. The ammonia present in weak liquor is in two forms classified as "free" and "fixed". The free ammonia is that which is readily dissociated by heat, such as ammonium carbonates, sulfides and cyanides.

The fixed ammonia requires the presence of strong alkali to effect displacement of the ammonia from the compound in which it is present; examples include ammonium chloride, thiocyanate, ferrocyanide, sulfate. In the ammonia still "free" ammonia and acidic gases are removed by passing weak ammonia liquor down through a column over a series of plates equipped with bubble caps and overflow pipes. The liquor is heated by an upward flow of steam which vaporizes ammonia and volatile acidic gases. The vapors leave the top of the "free leg" of the ammonia still and pass to the dephlegmator. In the dephlegmator the vapors are partially cooled and excess water is removed and returned to the still. The vapors leaving the still consist of 10 to 25 percent ammonia. Most of the balance is water vapor with some acidic gases and neutral oils. Liquor leaving the "free leg" of the ammonia still may be sent to the dephenolizing unit if the weak liquor was not dephenolized by solvent extraction before being fed to the ammonia still. Weak liquor from which phenols and "free" ammonia have been removed will be treated with "milk of lime" (calcium hydroxide solution). The calcium hydroxide reacts with fixed ammonium salts, primarily ammonium chloride, according to the following reaction.



The ammonia is stripped from the solution by steam in a process similar to that used to remove free ammonia from the original weak liquor. The vapors leaving the ammonia still are added to the gas stream in the semidirect process and sent to Ammonia Absorption (Process 26). Alternatively, concentrated ammonia liquor may be produced. If concentrated liquor is produced the acidic gases are separated by scrubbing the vapors from the

still with an alkali. The organic matter is separated by condensation and washing with organic solvents or with solid absorbents. Table B-10, Appendix B, gives an analysis of crude liquor from one plant.

2. Input Materials - Weak ammonia liquor is treated in the ammonia still. The quantities of ammoniacal liquor and its composition depend on the carbonization temperature, moisture content and chemical make-up of the coal charged. Table 26 gives analysis of weak ammonia liquor from three plants.^{1,2,3}

Table 26. ANALYSES OF WEAK AMMONIA LIQUOR FROM THREE PLANTS
(grams per liter)

Composition	Plant A ^a	Plant B ^a	Plant C ^b	Estimated ^c
Ammonia, total	6.54	7.06	5.6	4.8
free ^d	3.35			
fixed ^e	3.19			
Sulfide as H ₂ S		0.138	0.29	
Carbonate as CO ₂		0.81		
Thiosulphates as H ₂ S ₂ O ₃			1.10	
Cyanides as HCN			0.03	0.05
Sulphates as H ₂ S ₂ O ₄			0.17	
Total Sulphur as S			0.82	
Total phenols			2360 ppm	2.7
Tar material			Trace	
Chemical oxygen demand				12.4
Biochemical oxygen demand, 5-day				10.2
Oils				1.2
Thiocyanates				0.8

^a Reference 1.

^b Reference 2, analysis of liquor before phenol removal.

^c Reference 3, analysis of liquor before phenol removal.

^d Ammonium carbonate, bicarbonate, sulfide, cyanide and carbamate.

^e Ammonium chloride, thiocyanate, ferrocyanide, thiosulfate and sulfate.

Milk of lime used contains about 40 grams of lime per liter of solution.⁴ From 1 to 1.25 kilograms lime are consumed per ton* of coal carbonized.⁵

Yields of ammonia produced by carbonizing coal in by-product coke plants range from 2.5 to 3.0 kilograms per ton*.⁴

3. Operating Parameters - Vapors leave the top of the still at temperatures of 98 to 104°C.⁵

4. Utilities - About 200 kilograms of steam at 14 kg/sq cm (200 psig) and 38°C superheat are required in a 2800-ton*-per-day-capacity coke plant.⁶

5. Waste Streams - The waste sludge is alkaline, has brown or red-brown color, and contains about 0.03 gram ammonia and 1.0 gram lime per liter.^{1,4}

The waste volume depends on the amount of steam added, method of recovery, strength of ammonia liquor, and volume of milk of lime added. Approximate wastes produced per ton* of coal carbonized are: 80 liters if only condensed ammonia liquor is charged to the still, and 340 liters if gases are scrubbed with water to collect ammonia and the resultant solution is charged to the still along with condensed ammonia liquor. The waste produced from the first process amounts to 150 to 160 percent of the original liquor volume and contains 10 to 20 percent by volume of milk of lime.¹

All the fixed ammonium salts of the original liquor are converted to the corresponding calcium compounds, the chloride, sulfate, thiosulfate, and thiocyanate. Some of the organic matter present in the original liquor is left in the still waste, but the total concentration is greatly reduced and physical conditions altered.¹ Waste contains about 1000 to 2500 parts per million of phenols.⁷ Analyses of wastes produced from ammonia still are presented in Table 27.^{1,3}

* Metric ton (1000 kg)

Table 27. ANALYSES OF WASTE LIQUOR FROM AMMONIA STILL
(grams per liter)

Composition	Plant A ^a	Plant B ^a	Estimated ^b
Ammonia, total	0.041	0.0034	0.3
free	N.A.	0.0034	
fixed	N.A.		
Alkalinity as CaO	1.57	1.44	
pH			10.7
Chemical oxygen demand			6.0
Biochemical oxygen demand, 5-day			4.2
Sulfide as H ₂ S		0.75	
Carbonate as CO ₂		0.37	
Oils			0.17
Phenols			1.15
Cyanides			0.025
Thiocyanides			0.55

^a Plants referred to in Table 27 Reference 1.

^b Reference 3, phenols are not extracted from the input materials.

6. EPA Source Classification Code - None exists.

7. References -

1. Wilson, Jr. P.J. Ammonical Liquor. Chapter 32. In: Chemistry of Coal Utilization, Volume II, Lawry, H.H. (ed.). New York, John Wiley and Sons, Inc., 1945. p. 1371-1392.
2. Elliott, A.C., and A.J. Lafreniere. Solvent Extraction of Phenolic Compounds from Weak Ammonia Liquor. Waste and Sewage Works. R325-R332, 1964.
3. Fisher, C.W., R.D. Hepner and G.R. Tallon. Koppers Company, Inc., Coke Plant Effluent Treatment Investigations. Blast Furnace Steel Plant. 315-320. May 1970.

4. Ammonia and Ammonium Salts. Chapter 10. In: Coal, Coke and Coal Chemicals, Chemical Engineering Series, Wilson, Jr. P.J., and J.H. Wells. (eds.). New York, McGraw Hill Book Co., 1950. p. 289-333.
5. Manufacture of Metallurgical Coke and Recovery of Coal Chemicals. In: The Making, Shaping, and Treating of Steel, Ninth Edition, McGannon, H. E. (ed.). Pittsburg, Pennsylvania. U.S. Steel Company, 1971.
6. Ess, T.J. The Modern Coke Plant. In: Iron and Steel Engineer. C3-C36, January 1948.
7. Gollmar, H.A. Coke and Gas Industry. Industrial and Engineering Chemistry. 39:596-601. 1947.

Ammonia Absorption

1. Function - Ammonia formed during coking is recovered by reaction with sulfuric acid to form ammonium sulfate. Ammonia exists in the gas phase and in aqueous solution in ammonia liquor. The ammonia-containing gas that is scrubbed with dilute sulfuric acid may be:

- (1) the total vapor, after condensation of tar (direct process),
- (2) ammonia which has been removed from the gas by scrubbing with water and then from the scrubber water and dilute ammonia liquor by distillation and treatment with alkali (indirect process), or
- (3) ammonia removed from the liquor produced during carbonization by distillation and alkali treatment and added to the gas stream (semi-direct process).

The semi-direct process is used most extensively at present. The ammonia may be contacted with dilute sulfuric acid nearly saturated with ammonium sulfate in a spray tower in the Otto or Wilputte processes, or by bubbling the gas through a large tank filled with liquid called a saturator (usually built before 1930). In any case ammonium sulfate crystals precipitate from the saturated ammonium sulfate - sulfuric acid solution and form a slurry. The slurry is sent to a crystallizer (Process 19) to complete the precipitation process and allow crystal growth. In the Otto process pyridine and other tar bases are recovered separately from the ammonia. The gas from the saturator is sent to the acid separator for removal of any mist carryover, and then to the light oil recovery plant (Process 20).

2. Input Materials - Gases from the electrostatic precipitator and gaseous ammonia from the still are inputs to the process. For one kilogram of ammonia present in the input gases, 2.88 kilograms of sulfuric acid are used.¹

3. Operating Parameters - The gases enter the absorber at about 55°C.¹

4. Utilities - The gas-liquid contactor requires electricity for pumping and fans for gas transport.

5. Waste Streams - Some particulate is evolved.

6. EPA Source Classification Code - None exists.

7. References -

1. Ralph Stone and Co., Inc. Forecasts of the Effects of Air and Water Pollution Controls on Solid Waste Generation. Environmental Protection Agency. Publication Number PB-238819. December 1974.
2. Manufacture of Metallurgical Coke and Recovery of Coal Chemicals. In: The Making, Shaping, and Treating of Steel, Ninth Edition, McGannon, H. E. (ed.). Pittsburg, Pennsylvania. U.S. Steel Company, 1971.

Crystallization and Filter Drying

1. Function - The ammonium sulfate crystals precipitated in the crystallizer accumulate as a slurry in the bottom. The slurry is removed from the crystallizer and pumped to the slurry tank where the salt settles the liquid overflows and returns to the ammonia absorber. From this tank crystal sulfate slurry is fed to centrifugal dryers or a rotary filter dryer. In the rotary filter dryer, the liquor is removed and hot air, under slight vacuum, dries the sulfate. The liquor is pumped back to the ammonia absorber. Chemically pure ammonium sulfate is a white salt that contains 25.78 percent ammonia. The commercial salt varies in color from white to tan and contains 25.0 to 25.7 percent ammonia. The final dried material contains approximately 0.1 percent water.¹ The free acid content of the finished sulfate ranges from 0.05 to 0.3 percent by weight.²

2. Input Materials - Solution from absorber.

3. Operating Parameters - The hot air to the dryer is maintained under slight vacuum.

4. Utilities - Not available.

5. Waste Stream - A fine mist of sulfuric acid may be evolved.

6. EPA Source Classification Code - None exists.

7. References -

1. Manufacture of Metallurgical Coke and Recovery of Coal Chemicals. In: The Making, Shaping and Treating of Steel, Ninth Edition, McGannon, H.E. (ed.). Pittsburgh, Pennsylvania, U.S. Steel Company, 1971. p., 168-170.
2. Ammonia and Ammonium Salts. Chapter 10. In: Coal, Coke and Coal Chemicals. Chemical Engineering Series, New York, McGraw-Hill Co., Inc., 1950.

Light Oil Recovery

1. Function¹- The gases leaving the ammonia absorber at 50 to 60°C are cooled to 20°C in a tower by direct contact with water. The gas is then scrubbed in a tower with petroleum wash oil which removes the light oil from the gas. The gas, free from all by-products, then flows to the gas holder. The wash oil, enriched with 2 to 3 percent light oil, is preheated to a temperature of 100 to 140°C and then distilled with direct steam to remove about 90 percent by volume of light oil. The mixture of light oil and steam passes out the top of the still through separators which remove water, and finally through a condenser to crude storage. The debenzolized wash oil leaving the bottom of the still is cooled and the water and impurities are removed. The oil is recirculated to the gas absorber.

The light oil is a clear yellow brown oil containing well over a hundred constituents, most of them in very low concentrations.¹ Principal usable constituents are benzene (60-85%), toluene (6-17%), xylene (1-7%) and solvent naphtha (0.5-3%). Light oil constitutes approximately 1 percent of the coal carbonized.¹

2. Input Materials - Gas from the absorber, water and petroleum wash oil. Wash oil consumption may run 0.07 to 0.1 kilogram per ton of coal carbonized, while a circulation rate of 400 to 800 liters per ton of coal carbonized may be used. About 80 grams of steam are used per liter of wash oil in the stripping still.²

3. Operating Parameters - Temperature of the gas entering the scrubber is 15 to 30°C. Temperature of the wash oil entering the process is 17 to 32°C. The petroleum wash oil normally used for this absorption process has a boiling range of 270 to 350°C.¹

4. Utilities - Approximately 1400 kilograms of steam at 14.0 kg/sq. cm. (200 psig) and 38°C superheat are required for a plant with 2800 tons of coking capacity.²

5. Waste Stream - Some particulate is evolved. Liquor containing tar is disposed of, but quantities generated are not available.

6. EPA Source Classification Code - None exists.

7. References -

1. Manufacture of Metallurgical Coke and Recovery of Coal Chemicals.
In: The Making, Shaping, and Treating of Steel, Ninth Edition,
McGannon, H.E. (ed.). Pittsburgh, Pennsylvania, U.S. Steel
Company. 1971. p. 165-177.
2. Ess. T.J. The Modern Coke Plant. Iron and Steel Engineer.
C3-C36, January 1948.

Fractionation and Refining of Light Oil

1. Function - Light oil may be sent to a secondary products recovery plant that produces benzene, toluene, xylene and other compounds. The light oil fraction is washed with concentrated sulfuric acid, neutralized with an alkali, and fractionated into desired products.

Fractionating and refining of light oil is accomplished over a considerable range of temperatures. The light oil charge is heated in a still by gradual increase in temperature. At a still temperature of 65°C, a product containing benzene, and some carbon bisulphide is evolved. At 80°C, a product of crude benzene is evolved; at 110°C, crude toluene; at 120 to 140°C, light solvent naphtha; and at 150°C, heavy solvent naphtha. The residue in the still is wash oil and naphthalene, the latter solidifying when cooled. Usually complete fractionation is not carried out; three fractions are more usual. When pure compounds are required the fractions may be redistilled.¹

About 60 percent of the light oil produced is refined at coke plants. The principal products are: benzene, toluene and xylene. The remainder of the light oil is sold to other processors.²

2. Input Materials - Light oil.

3. Operating Parameters - Fractionation is carried out at temperatures from 65 to 140°C.

4. Utilities - No data available.

5. Waste Streams - Wastes from refining light oils include acid and alkali after washing light oil with sulfuric acid and caustic soda.³ Particulate is also emitted.

6. EPA Source Classification Code - None exists.

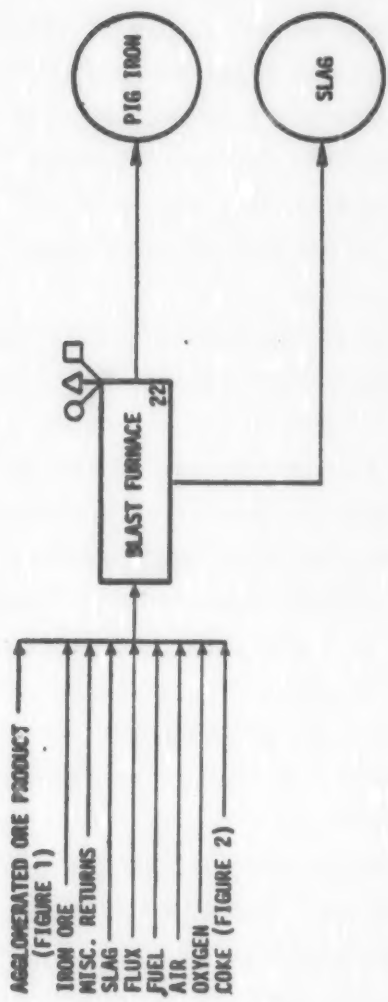
7. Reference -

1. Ess, T.J. The Modern Coke Plant. Iron and Steel Engineer. C3-C36, January 1948.

2. Perch, M., and R.E. Muder. Coal Carbonization and Recovery of Coal Chemicals. In: Riegel's Handbook of Industrial Chemistry, Seventh Edition, New York, Van Nostrand Reinhold, 1974. p. 103-206.
3. Gollmar, H.A. Coke and Gas Industry. Industrial Engineering Chemistry. 39:596-601, May 1947.

PIG IRON PRODUCTION

Figure 4 illustrates the pig iron production in a blast furnace. A very limited amount of iron is produced as sponge iron by another method called direct reduction.¹ Due to its limited application, this method is not described in this report.



○ GASEOUS EMISSIONS
 △ LIQUID WASTES
 ◇ SOLID WASTES

Figure 4. Pig iron production.

Note: Material handling and storage which is not shown on the flow sheet is required through pig iron production and has fugitive emissions, liquid waste, and solid waste.

Blast Furnace

1. Function - The agglomerated product and ore are stockpiled. In colder climates three to four months supply is stored. From storage, it is moved to surge hoppers at the blast furnace where it is weighed and transferred to the top of the blast furnace by skip hoist or by belt conveyor. Coke, and limestone used in blast furnaces are not stored near the furnace area in large quantities, and if possible, are consumed directly as they are received. Charging of the furnace is automatically controlled.

The blast furnace reduces the iron ore to produce pig iron. Iron-bearing materials (iron ore, sinter pellets, mill scale, iron or steel scrap), coke, and fluxes (limestone and others) are charged into the top of the furnace in a fixed pattern of coke to ore to stone. The heated blast air is introduced into the furnace above the hearth line through tuyeres. In some instances fuel oil, powdered coal, natural gas or oxygen is blown into the bottom. The iron ore descends down the furnace and is reduced and melted by the countercurrent flow of hot reducing gases created by the partial combustion of coke. Hot metal from the furnace is tapped into torpedo cars and weighed on the hot metal track scale. After the metal is transferred to a charging ladle, a crane transports it to the steelmaking vessel. Molten slag is removed from the furnace through separate tapping holes which are at an higher elevation than the molten iron tap hole. The slag discharged from the blast furnace is collected in slag pits or slag timbles. The hot molten pig metal typically contains 4.1 percent C, 0.9 percent Si, 0.026 percent S, 0.296 percent P and 0.35 percent Mn.¹ Analysis of limestone and coke used in blast furnaces is given in Tables A-4 and A-5, Appendix A.

2. Input Materials - In the United States in 1973, an average of 1.676 tons of metalliferous materials were consumed in blast furnaces for each ton pig iron produced.²

Table 28 lists approximate inputs and outputs of one blast furnace.¹

Table 28. EXAMPLE OF BLAST FURNACE MATERIAL BALANCE

Material	Weight, tons*
INPUTS	
<u>Iron bearing burden</u>	
Iron ore	0.3075
Flux sinter	1.226
Scrap	0.099
<u>Flux</u>	
Limestone	0.008
Gravel	0.008
<u>Fuel</u>	
Coke	0.514
Natural gas	0.021 (0.027 million liters)
<u>Blast</u>	
Air	1.639 (1.254 million liters)
Moisture	0.016 (0.019 million liters)
OUTPUTS	
Hot metal	1.0
Slag	0.25
Runner scrap	0.006
Top gas	2.461 (1.8 million liters)
Moisture	0.079 (0.093 million liters)
Dust and sludge	0.042

* Metric tons (1000 kg)

3. Operating Parameters - The furnace operates at about 1540°C. Many of the older furnaces operate at top-pressures of about 7030 kgs/sq meter (10 psi). Newer plants operate at top-pressures of 14,060 kgs/sq meter (30 psi) and future furnaces at 42,200 to 49,200 kgs/sq meter (60 to 70 psi).³

4. Utilities - Table 29 shows the daily utility requirements of a typical two-furnace plant.^{1,4} This blast furnace plant operation consumes an average of 50.7 kilowatt-hours of electricity per ton of pig iron produced. This blast furnace plant requires an average of 429 liters per second per blast furnace for recirculation, make-up and service water. In addition to this amount, 658 liters of water per second per furnace are needed for boiler house, turbine, condenser, and use as potable water.¹

5. Waste Streams - Particulate emissions from blast furnaces are minimal since a high degree of particulate emission control is necessary to keep the stoves (heat exchangers) from plugging. Without controls, about 75 kilograms of particulate per ton of product is emitted.⁵ Particulates are also emitted during each tap, and these emissions enter the atmosphere by passing through the sides and roof of the cast house. Blast furnace slips, which create emissions that bypass the control devices, occur occasionally. Table 30 presents composition data for collected blast furnace dust;⁶ Table 31 gives a size analysis of the dust.⁶ The collected dust is usually utilized as feed to the sinter machine. Composition and size distribution of particulates escaping to the atmosphere were not available.

About 6 tons* of gases are evolved for every ton of iron produced from the blast furnace. Table 32 gives an analysis of gases produced at one plant.⁷ Heating value of the raw gas (produced at the plant mentioned in Table 32) is 800 kilocalories per cubic meter (90 Btu/ft³) and the moisture content is 2 percent. The gases leave the furnace with a dust concentration of 27.5 grams per cubic meter (12 grains per cubic foot).⁷ Part of this gas is used for heating purposes. The gases leave the furnace at temperatures of 180 to 280°C. The flow rate of the gases is a function of the coke feed rate. Total gas volume increases linearly with increase of the coke feed rate.

* Metric tons (1000 kg)

Table 29. UTILITIES REQUIREMENTS OF A SELF-CONTAINED BLAST-FURNACE PLANT WITH TWO FURNACES,
PRODUCING A TOTAL OF 3810 NET TONS* OF HOT METAL PER DAY^a

Utility	Quantity required daily	
	English	Metric
Recirculating water	16,012,800 gal.	60.61 x 10 ⁶ liters
Make-up water	259,200 gal.	0.981 x 10 ⁶ liters
Other service water	3,326,400 gal.	12.59 x 10 ⁶ liters
Water to utilities (boiler house, turbine condensers, etc.)	29,952,000 gal.	113.37 x 10 ⁶ liters
Potable water	72,000 gal.	0.273 x 10 ⁶ liters
Coke-oven gas	1,008,000 cu. ft.	28.55 x 10 ³ cubic meters
Natural gas for heat	172,000 cu. ft.	4.87 x 10 ³ cubic meters
Natural gas for heat (3 months)	20,448,000 cu. ft.	0.579 x 10 ⁶ cubic meters
Boiler house fuel		
Fuel oil	172,800 gal.	0.654 x 10 ⁶ liters
Blast-furnace gas	446,400,000 cu. ft.	12.640 x 10 ⁶ cubic meters
Compressed air at 5.6 kgs/sq. cm. (80 psi)	1,152,000 cu. ft.	32.63 x 10 ³ cubic meters
Steam at 14.1 kgs/sq. cm. (200 psi) and 38°C (100°F) superheat	9,600,000 lb	4,354,560 kilograms
AC electricity - purchased	151,200 kilowatt hours	151,200 kilowatt hours
DC electricity - own-produced	42,000 kilowatt hours	42,000 kilowatt hours

^a Volumes of gases refer to 16°C (60°F) and 1 kg/sq. cm. (30 in. Hg), unless otherwise specified.

* Metric tons (1000 kg)

Table 30.. CHEMICAL COMPOSITION OF DRY, BLAST-FURNACE FLUE DUST

Component ^a	Weight percent	
	Range for several plants	Midwest plant
Iron	36.5 - 50.3	47.10
Ferrous oxide	N.A.	11.87
Silicon dioxide	8.9 - 13.4	8.17
Aluminum oxide	2.2 - 5.3	1.88
Magnesium oxide	0.9 - 1.6	0.22
Calcium oxide	3.8 - 4.5	4.10
Sodium oxide	N.A.	0.24
Potassium oxide	N.A.	1.01
Zinc oxide	N.A.	0.60
Phosphorus	0.1 - 0.2	0.03
Sulfur	0.2 - 0.4	N.A.
Manganese	0.5 - 0.9	0.70
Carbon	3.7 - 13.9	N.A.

N.A. - not available

^aTests on blast furnace scrubber samples from a plant in Midwest Indiana, showed the presence of cadmium 14 ppm.⁴

Table 31. SIZE ANALYSIS OF FLUE DUST FROM U.S. BLAST FURNACES ^a

Size		Range, percent
U.S. series sieve	Microns	
20	833	2.5 - 20.2
30	589	3.9 - 10.6
40	414	7.0 - 11.7
50	295	10.7 - 12.4
70	208	10.0 - 15.0
100	147	10.2 - 16.8
140	104	7.7 - 12.5
200	74	5.3 - 8.8
-200	-74	15.4 - 22.6

^aDust collected in particulate control devices.

Table 32. ANALYSIS OF FURNACE GAS

Constituent	Percent by volume
CO ₂	15.8
CO	25.6
H ₂	3.0
CH ₄	--

Dry cyclones, wet scrubbers, and electrostatic precipitators are used for controlling emissions from blast furnaces. Venturi scrubbers or electrostatic precipitators clean blast furnace flue gas to a particulate concentration of 0.023 grams per cubic meter.⁸

Wastewater from the blast furnace plant includes furnace cooling water and scrubber water. The furnace cooling water leaves the furnace and scrubber water. The furnace cooling water leaves the furnace essentially as received except for the heat added. The scrubber water contains mainly ammonia, phenol, cyanide, fluorides, and carbon monoxide. Table 33 shows typical liquid waste emission rates.⁹

Slag from the blast furnace is tapped periodically. The slag is handled usually in one of four ways: directly into cinder ladles and conveyed to a dump area or to other nearby processors; granulated; directly to cooling pits; or into lightweight aggregate. Slag contains sulfide compounds that are emitted during quenching. Approximately 0.25 of slag are produced for each kg. of pig iron.¹

6. EPA Source Classification Code -

Blast furnace ore charging - 3-03-008-01.

Blast furnace agglomerates charging - 3-03-008-02.

7. References -

1. The Manufacturing of Pig Iron. In: The Making, Shaping and Treating of Steel, Ninth Edition. McGannon, H.E. (ed.). Pittsburgh, Pennsylvania, U.S. Steel Company, 1971. p. 428
2. Reno, H. T. Iron and Steel. In: Minerals Yearbook, Bureau of Mines, Washington, D.C., Government Printing Office, 1973.
3. Uys, J. M., and J. W. Kirkpatrick. The Beneficiation of Raw Materials in the Steel Industry and Its Effects upon Air Pollution Control. Journal of Air Pollution Control Association. p. 20-27, January 1963.
4. Yost, K.J. et al. Purdue University. Flow of Cadmium and Trace Metals. Volume I. National Science Foundation. Project Number PB-229478. June 30, 1973.

Table 33. POLLUTANTS IN WASTEWATER FROM BLAST FURNACE

Waste material	Old plant ^a	Typical plant ^b	Advanced plant ^c
Suspended solids, kg/ton ^d	28.2	22.2	37.9
Phenols, gms/ton ^d	7.8	7.3	7.4
Cyanides, gms/ton ^d	9.9	9.4	9.4
Fluorides, gms/ton ^d	16.4	15.3	15.3
Ammonia, gms/ton ^d	7.8	7.3	7.4

^a Utilizing older, relatively inefficient processing technology.

^b May have more than one blast furnace with daily capacities of 1000 tons* of iron.

^c Operating at an advanced technology, has one or more blast furnaces with daily capacities of 1000* tons or more iron and fully automated with raw materials fed under computer control.

^d Per metric ton of pig iron product

5. Iron and Steel Mills. In: Compilation of Air Pollution Emission Factors. Environmental Protection Agency. Contract Number CPA-22-69-119. April 1973. p. 7.5-4.
6. Varga, J. Jr., and H. W. Lownie. Final Technological Report on A Systems Analysis Study of the Integrated Iron and Steel Industry. Battelle Memorial Institute, Columbus, Ohio. May 1969.
7. Labee, C. J. Steel Making at Weirton. Iron and Steel Engineer. October 1969.
8. Bramer, H. C. Pollution Control in the Steel Industry. Environmental Science and Technology. 1004-1008, October 1971.
9. Industrial Waste Profiles No. 1 - Blast Furnace and Steel Mills. Volume II. The Cost of Clean Water. Federal Water Pollution Control Administration. FWPCA Contract Number 14-12-98. September 28, 1967. p. 55.

STEEL PRODUCTION

Pig iron is refined into steel in furnaces by reducing the level of impurities, carbon content, and adding alloying compounds. Modern steelmaking processes utilize a large percentage of steel scrap in addition to molten pig iron and various alloying compounds. Molten steel from the furnaces is usually teemed into ingot molds for further processing. The ingots are then subjected to roughing and finishing operations. Figure 5 illustrates the processes of steel manufacturing.

The three basic types of steel furnaces are in use: electric, open-hearth, and basic oxygen. A significant number of open-hearth and electric furnaces also incorporate oxygen lancing because it permits higher production rates. The four major phases of furnace operations are charging, meltdown, refining, and teeming.

Atmospheric emissions vary substantially among these phases of furnace operation and are increased by the use of oxygen lancing. From the standpoint of potentially hazardous emissions, however, the composition of furnace emissions is primarily a function of the grade of steel being produced (i.e., the amount and type of alloying compounds charged to the furnace) and the scrap metal charge.

Tables F-1 through F-3, Appendix F give details of types and numbers of steel furnaces and their capacities in the United States.

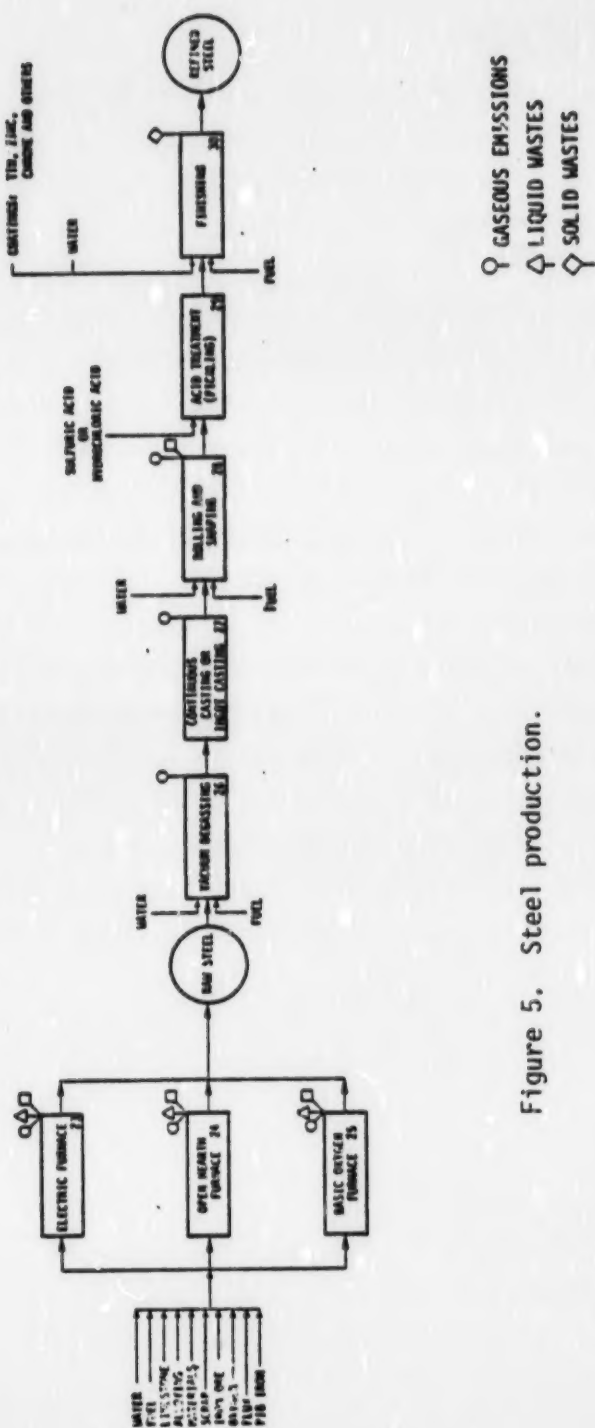


Figure 5. Steel production.

Electric Furnace

1. Function - Two types of electric furnaces, the arc furnace and the induction furnace, are used to produce steel. The arc furnace is used to produce high-alloy steels, as well as a considerable amount of mild steel. The induction furnace produces primarily speciality and high alloy steels with no real emission problems and therefore is omitted in the remainder of this report.

Cranes with special designed drop-bottom buckets are used to charge raw materials and alloying materials into the furnace.¹ Charging is done usually through the swing-out roof of the arc furnace. Some units are charged through their doors or openings or via a chute. Practically all modern arc furnaces for steelmaking are top-charged. At the time of charging, the electrodes are moved out of the way. After charging of the molten metal, light and heavy scrap, alloying material, and fluxes, the furnace roof is returned to close the arc furnace and the electrodes are lowered to about 2.5 centimeters above the charge.² Many times a bank is built in front of the arc furnace doors with refractory material (dolomite) to form a dam that keeps molten metal from slopping out of the doors. As current is applied through the electrodes, the charge is melted. Oxidation occurs in varying degrees, from the time molten metal begins to form, until the entire charge is in solution. During this period phosphorus, silicon, manganese, carbon, and other materials are oxidized. Slagging commences to form and is carefully controlled throughout the operation. Oxygen lancing is often used to increase production rates. At the end of the process, the electrodes are raised. In taping, depending on the type of furnace, fixed or tilting, the tap hole is opened or the furnace is tilted so that the steel is tapped from the furnace into a ladle. Slagging practice varies from shop to shop. Slag removal may be done prior to tapping, during, or at the end of the tap. A crane moves the ladle either to the pouring platform, where the steel is poured into molds, or to continuous casting, or to a vacuum-degassing station,² or to a gas-

eous decarburization vessel (AOD).

2. Input Materials - Table 34 gives production data for a particular electric furnace shop.³ Because of their current-carrying capacity, graphite electrodes are used almost exclusively in electric steelmaking furnaces.

3. Operating Parameters - The charge is tapped at 1570°C, but if vacuum degassing or other processes follow the tapping temperature could be as much as 100°C higher. Table 35 gives operating data of a particular electric furnace shop.³ The furnace operates at essentially atmospheric pressure.

4. Utilities - The utilities required vary considerably depending on a number of factors: practice; furnace size; product grade; vacuum degassing or other processes following. Table 35 gives the power requirements for a particular electric furnace.³ Depending on furnace efficiency, and hot metal practice, electric furnace requires about 247 to 375 kilowatt-hours of power per ton of steel produced.³ Approximately 50 to 75 liters of cooling water per second is required.²

5. Waste Streams - Particulate emissions from electric furnaces consist primarily of oxides of iron, manganese, aluminum, calcium, magnesium and silicon. Tables 36 and 37 present typical data on composition of emissions from some electric furnaces.⁴ Many new electric furnace installations use baghouses for controlling emissions.⁵ Table 38 gives particle size distribution of emissions from an electric-arc furnace.^{6,7,8} The uncontrolled particulate emission rate is approximately 4.6 kilograms per metric ton of metal without oxygen lancing and about 5.5 kilograms per ton of metal produced with oxygen lancing. Other emissions include gaseous fluorides at 0.006 kilogram per ton* and particulate fluoride at 0.119 kilogram per ton* of metal produced.⁹

Depending upon the amount of pig iron used in the charge, about 9 kilograms of carbon monoxide gas is emitted per ton* of metal produced.⁹ The gases generated during the meltdown and refining steps of furnace

* Metric ton (1000 kg)

Table 34. PRODUCTION DATA FOR A PARTICULAR ELECTRIC FURNACE SHOP

Charge, kg	Practice		
	Cold charge	35% hot metal	50% hot metal
Hot metal charge	0	63,500	90,700
Total charge	181,400	181,400	181,400
Burnt lime	3,600	3,600	3,600
Raw limestone	6,000	6,400	6,400
Number of charges	3	2	1
Net ingot per heat	164,835	161,387	159,845
Percent hot metal	0	34.8	49.8
Percent yield	90.4	88.5	87.7

TABLE 35. OPERATING DATA FOR A PARTICULAR ELECTRIC FURNACE SHOP

Charge	Practice		
	Cold charge	35% hot metal	50% hot metal
kWh per heat	75,000	53,100	48,000
O ₂ per heat, liters	3,346,000	3,158,000	4,769,000
kWh per net ingot	375	263	247
O ₂ per net ingot, liters	18,400	17,800	27,100
Tap to tap hr per heat	4.58	3.58	3.17
Ingot tons per tap to tap hr	36.02	45.09	50.44
Number of heats per roof	90	70	60
Number of heats per side wall	105	95	90
Kilograms electrodes per net ingot tons (metric)	4.76	4.13	4.13

Table 36. CHEMICAL COMPOSITION OF ELECTRIC FURNACE DUSTS

(percent by weight)

Element or Compound	Sample designation					
	A	B	C	D	E	F
FeO	4.2	N.A.	N.A.	N.A.	N.A.	4 - 10
Fe ₂ O ₃	35.04	50.55	52.62	52.05	50.05	19 - 44
Cr ₂ O ₃	0.00	0.56	0.00	0.15	13.87	0 - 12
MnO	12.10	12.22	5.34	1.29-2.58	N.A.	3 - 12
NiO	0.30	N.A.	tr	tr	3.18	0 - 3
PbO	N.A.	N.A.	3.47	0.81-1.08	N.A.	0 - 4
ZnO	N.A.	N.A.	8.87	1.24-2.48	N.A.	0 - 44
SiO ₂	8.80	5.76	6.78	3.85	5.50	2 - 9
Al ₂ O ₃	12.90	5.85	2.55	14.61	N.A.	1 - 13
CaO	14.90	2.60	6.72	1.40-4.20	9.80	5 - 22
MgO	7.90	7.78	3.49	1.66-4.98	6.64	2 - 15
S	0.26	tr	0.59	N.A.	N.A.	0 - 1
P	0.10	0.28	N.A.	N.A.	N.A.	0 - 1
C	2.30	N.A.	N.A.	N.A.	N.A.	2 - 4
Alkalies	1.20	4.76	N.A.	N.A.	2.50	1 - 11

Note: N.A. - not available, tr - trace

Sample A - Single 20-ton furnace. Plant specializing in tool and die steels.

Sample B - Representative sample from plant with four 75-ton and two 200-ton furnaces producing low-alloy and stainless steels.

Sample C - Single 100-ton furnace producing low-alloy steels for plate.

Sample D - Single 100-ton furnace producing low-alloy steels for plate.

Sample E - Single 70-ton furnace producing stainless steel.

Sample F - Representative samples from multiple-furnace shop. Furnaces vary in size from 4 to 200 ton producing low-alloy and stainless steels.

Table 37.. CHANGES IN COMPOSITION OF ELECTRIC FURNACE DUST
DURING A SINGLE HEAT

Product	Composition, weight percent								
	Fe ₂ O ₃	Cr ₂ O ₃	MnO	SiO ₂	CaO	MgO	Al ₂ O ₃	P ₂ O ₅	SO ₂
Melting	56.75	1.32	10.15	9.77	3.39	0.16	0.31	0.60	2.08
Ore oxidation	66.00	1.32	5.81	0.76	6.30	0.67	0.17	0.59	6.00
Oxygen lancing	65.37	0.86	9.17	2.42	3.10	1.83	0.14	0.76	1.84
Refining	26.60	0.53	6.70	tr	35.22	2.72	0.45	0.55	7.55

Table 38. PARTICLE SIZE DISTRIBUTION OF EMISSIONS FROM
A PARTICULAR ELECTRIC-ARC FURNACE
(percent by weight)

Size, microns	Reference		
	9	10	11
0 - 3			18
0 - 5	71.9	67.9	
3 - 11			64
5 - 10	8.3	6.8	
11 - 25			7
10 - 20	6.0	9.8	
>25			11
20 - 44	7.5	9.0	
>44	6.3	6.5	

operation are collected at temperatures ranging from 650 to 980°C.¹⁰

As stated earlier, emission composition is dependent upon the type of steel produced and composition of the charge.

Some spilling may occur when the slag is transferred to slag processing operations.

Particulate collected in the emission control systems is sometimes recycled to the sintering operation (much of it not recyclable because of zinc contamination). Water pollution is not a problem unless a scrubber is used, at which time high solid loadings are encountered. Occasionally, extremely high contents of suspended solids, on the order of 5000 ppm, may be present in the cooling water.¹¹

6. EPA Source Classification -

Electric-arc furnace with lancing - 3-03-009-04.

Electric-arc furnace without lancing - 3-03-009-05.

7. References -

1. Yard, E. M., and P. D. Nyajust. Open-Hearths Replaced by Electric Furnaces. Iron and Steel Engineer. 72-75, July 1967.
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3. Rankin, W. M. Electric Furnace Steel Production, Houston Works, Armco Steel Corp. Journal of Metals 104-107, May 1968.
4. Varga, J. Jr., and H. W. Lownie. Final Technological Report on a Systems Analysis Study of the Integrated Iron and Steel Industry. Battelle Memorial Institute, Columbus, Ohio. May 1969.
5. Bramer, H.E. Pollution Control in the Steel Industry. Environmental Science and Technology. 1004-1008, October 1971.
6. Coulter, R. S. Smoke, Dust, Fumes Closely Controlled in Electric Furnaces. Iron Age. January 14, 1954.
7. Erickson, E. O. Electric Furnaces Steel Proceedings. 11: 156-160 (1953).

8. Dck, H. Journal of Air Pollution Control Association. 5:23-26 (1955).
9. Iron and Steel Mills. In: Compilation of Air Pollutant Emission Factors. Environmental Protection Agency, Research Triangle Park, N.C. Contract Number CPA-22-69-119. April 1973. p. 7.5-5.
10. Brough, J. R., and W. A. Carter. Air Pollution Control of an Electric Furnace Steel Making Shop. Journal of Air Pollution Control Association. 167-171, March 1972.
11. Miller, J. R. Impurities in Iron Ore, 1004-1008, Battelle Memorial Laboratories, Columbus, Ohio.

Open-Hearth Furnace

1. Function - Open-hearth furnaces accounted for 26.4 percent of steel production in 1973.¹ Although oxygen lancing is widely used to increase open hearth production rates, electric furnaces and basic oxygen furnaces (BOF) are currently preferred. An open-hearth furnace can produce 30 to 60 tons* of steel per hour compared with 300 or more tons* of steel per hour in a BOF.

The feed, consisting of limestone, light and heavy scrap, and normally molten pig iron, is charged to the reverberatory furnace and heated. Cold pig iron is used when molten pig iron is not available. In normal practice a predetermined quantity of iron ore is charged to provide low-cost iron units and oxygen for controlling the carbon content of the bath when the charge is melted. Silica, manganese, phosphorus, and sulfur impurities are oxidized and form into slag. The oxidized forms of chromium, vanadium, aluminum, titanium, tungsten, columbium, and zinc may also be present in the slag. The elements that may be present, such as copper, nickel, molybdenum, cobalt, tin, and arsenic are held in the iron because iron would have to be completely oxidized before these elements could be removed by oxidation. Some carbon in the charge is converted to carbon monoxide. Calcination of limestone produces carbon dioxide. When the molten steel bath is analytical at the grade of steel required, the molten contents of the furnace are tapped through the tap hole into the steel ladles. The alloying, recarbonizing, and deoxidizing materials are added to the molten metal before the slag starts flowing. The molten metal is poured into ingot molds for the particular final product. Slag is tapped into slag pots.²

2. Input Materials - Limestone, scrap, pig iron, molten iron, oxygen and alloying, recarbonizing and deoxidizing agents are used. The amounts of hot metal (molten pig iron) and scrap in the charge vary depending on availability of metal and scrap. The amount of iron ore charged in-

* Metric tons (1000 kg)

creases with the amount of molten iron used. Limestone varies from 5 to 8 percent of the metallic charge. Oxygen consumption ranges from 6,000 to 12,000 liters per ton* during oxygen lancing, with corresponding saving in tap to tap time of 10 to 25 percent and a decrease in fuel consumption of 18 to 35 percent using oxygen roof lances.²

3. Operating Parameters - The finishing temperature of steel in an open-hearth steel furnace is about 1595°C, varying according to composition and grade of steel.² The time required for charging and melting down of the scrap ranges from 2 to 4 hours.³

4. Utilities - Heat is usually supplied by combustion of fuel oil natural gas, tar, or combinations of these. Table 39 gives a typical heat balance of modern open-hearth furnace.² About 21,000 liters of water per ton of finished steel is used at open-hearth furnace plants; most of it is for indirect cooling.⁴ The furnace consumes about 8 kwh of electricity per ton* of ingot produced.²

Table 39. HEAT BALANCE OF A MODERN OPEN-HEARTH FURNACE,

kcal/ton* OF STEEL

Heat input	Quantity	Heat output	Quantity
Heat supplied to the furnace by the combustion of fuel	890,000	Sensible heat lost in stack gases	150,000
Heat originating by chemical reactions in the bath	110,000	Heat absorbed and utilized for plant use.	267,000
		Heat actually used to make steel	250,000
		Heat lost by radiation, escape of hot gases through doors etc., through system.	333,000
Total	1,000,000		1,000,000

* Metric ton (1000 kg)

5. Waste Streams - Emissions from each open-hearth furnace depend upon the furnace operation and type of charge in each furnace; and may vary during the cycle and from cycle to cycle. Emissions from open-hearth operations include particulates and fluorides. Fluoride emission rates depend on the fluorspar content of the fluxes. Uncontrolled particulate emissions from a furnace without oxygen lancing are about 4.2 kilograms per ton of product; with oxygen lancing, emissions range from 4.7 to 11.0 kilograms per ton*. These emissions include 50 grams of gaseous fluoride and 15 grams of particulate fluorides per ton of product.⁵ Tests conducted at major northwest Indiana steel plant showed a particulate concentration of 0.204 grams per cubic meter in a stack gas with a flow rate of 742 cubic meters per minute.⁶

The flow rates of gases range from 300 to 2100 cubic meters per minute. Gas temperatures range from 240 to 980°C; gases must be cooled before entering air pollution control equipment.⁷

Table 40 presents typical dust loadings of gas flow at different times of the meltdown.⁸

Table 40. PARTICULATE EMISSION - UNCONTROLLED

Function	Gas flow rate, cu meter/sec	Dust loading, grams/cu meter
Meltdown	28	1.78
Hot melt addition	30	4.30
Lime boil	31	6.18
Oxygen lancing	-	Up to 11
Refining	30	0.48

Table 41 gives particle size distribution from open-hearth furnaces and Table 42 presents data on chemical composition of particulate emissions.^{9,10,11}

* Metric ton (1000 kg)

Table 41. PARTICLE SIZE DISTRIBUTION OF EMISSIONS FROM
OPEN-HEARTH FURNACES
(percent)

<5 μ	5-10 μ	10-20 μ	>20 μ
50	Balance		Few
46	22	17	15
50-55	25-30	15-20	Bal

According to one Russian report, gases from steelmaking open-hearth furnaces contain very small amounts of carcinogens due to the high temperature occurring in the furnace.¹²

Electrostatic precipitators (98% removal efficiency) are the principal choice for emission control, although venturi scrubbers and baghouses (99% removal efficiency) are also used.¹³

About 8.5 to 10 kilograms of solid waste (dust collected in solid forms) per ton* of steel are generated.¹⁴ Depending on the amount of other metals present, such as zinc, this dust may be discarded or returned for sintering. The only potential water pollution source occurs when a scrubber is used to control emissions. The other source of waste water is the blowdown from the waste heat boiler if used.

6. EPA Source Classification Code -

Open-hearth with oxygen lancing - 3-03-009-01.

Open-hearth without oxygen lancing - 3-03-009-02.

7. References -

1. Reno, H. T. Iron and Steel. In: Minerals Yearbook, Bureau of Mines. (Preprint from the 1973) Washington, D.C., U.S. Government Printing Office, 1973.
2. The Making, Shaping and Treating of Steel, Ninth Edition. McGannon, H. E. (ed.). Pittsburgh, Pennsylvania, U.S. Steel Company, 1971. p. 525, 534, 635.

* Metric tons (1000 kg)

Table 42. CHEMICAL COMPOSITION OF OPEN-HEARTH PARTICULATE EMISSIONS, OXYGEN LANCING
(percent by weight)

Element or Compound	U.S. Steel Corp.		Steel Co. of Canada Hilton Works	United Kingdom United Steel Co.	Germany Dillingen	U.S. plant ^a
	Edgar Thomson	Homestead				
Fe ₂ O ₃	89.07	88.70	n.a.	88.5	79.65	n.a.
FeO	1.87	3.17	n.a.	2.2	0.31	n.a.
Total Fe	63.70	n.a.	63.5 - 68.0	n.a.	55.90	59.40
SiO ₂	0.89	0.92	1.16 - 1.56	0.4	0.47	2.00
Al ₂ O ₃	0.52	0.67	0.15 - 0.44	0.4	0.52	0.48
CaO	0.85	1.06	0.68 - 1.06	0.9	0.88	1.85
MgO	n.a.	0.39	0.32 - 0.44	1.5	1.86	1.12
MnO	0.63	0.61	n.a.	n.a.	0.61	n.a.
Mn	n.a.	n.a.	0.43 - 0.55	n.a.	n.a.	0.28
CuO	n.a.	0.14	n.a.	n.a.	n.a.	n.a.
Cu	n.a.	n.a.	0.11 - 0.16	n.a.	n.a.	0.08
ZnO	n.a.	0.72	0.26 - 2.04	n.a.	n.a.	n.a.
Zn	1.70	n.a.	n.a.	n.a.	n.a.	0 - 3.0
PbO	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Pb	0.50	n.a.	0.50 - 0.95	n.a.	n.a.	n.a.
SnO ₂	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Cr	n.a.	n.a.	0.06 - 0.11	n.a.	n.a.	n.a.
Ni	n.a.	n.a.	0.03 - 0.05	n.a.	n.a.	0.07
P ₂ O ₅	0.47	1.18	n.a.	n.a.	1.52	n.a.
P	n.a.	n.a.	0.06 - 0.12	0.3	n.a.	0.15
S	0.40	0.92	0.34 - 0.70	1.4	2.69	2.78
Alkalies	1.41	n.a.	0.56 - 1.71	n.a.	2.72	2.88

n.a. - data not available

^a Average for U.S. Plant.

3. Midwest Research, Inc. Particulate Pollutant System Study. Volume III. Handbook of Emission Properties. Contract Number CPA-22-59-104. May 1971.
4. Bramer, H. C. Iron and Steel. Chapter 14. In: Industrial Waste Water Control, Chemical Technology, A Series of Monographs. - Volume 2, Gurnham, C. F. (ed.). New York, Academic Press. 1965.
5. Iron and Steel Mills. In: Compilation of Air Pollutant Emission Factors. Environmental Protection Agency, Research Triangle Park, N.C. Contract Number CPA-22-69-119. April 1973. p. 7.5-4.
6. Yost, K. J. et al. Purdue University. The Environmental Flow of Cadmium and Other Trace Metals: Volume 1. National Science Foundation. Publication Number PB-229 478. June 30, 1973.
7. Engineering Science, Inc. Exhaust Gases from Combustion and Industrial Processes. Washington, D.C., October 1971.
8. Varga, J. Jr., and H. W. Lownie. Source of Air Pollution. In: Final Technological Report on A System Analysis Study of the Integrated Iron and Steel Industry, Battelle Memorial Institute, Columbus, Ohio. Contract Number PH 22-68-65. Department of Health, Education, and Welfare. May 15, 1969. V-11 p.
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14. Ralsh Stone and Co., Inc. Forecasts of the Air and Water Pollution Controls on Solid Waste Generation. Environmental Protection Agency. PB No. 238 819. December 1974.

Basic Oxygen Furnace

1. Function - The basic oxygen process-BOF, (as well as moderation processes Kaldo or Q-BOF) is being used increasingly because of its high production rates, simplicity and efficiency of operation. The BOF is predominant. Molten iron from the blast furnaces is brought to the basic oxygen furnace shop in railroad submarine ladle cars and steel scrap is brought in by both rail and truck. Fluxes such as burnt lime, limestone, burnt dolomite and fluorspar are handled by conveyor. A furnace charge could be scrap (30%), molten iron (70%), and fluxes. Oxygen is introduced through a water cooled lance and is blown onto the charge under pressure generally from 9.84 to 12.66 kg/cm. The process converts the hot metal into steel by oxidation of carbon, phosphorus, silicon, sulfur, and other impurities in the iron. The steel is tapped into a teeming ladle and alloying materials are added. The slag is tapped into slag pots. The overhead crane removes the teeming ladle from the transfer car and the molten steel is teemed into ingot molds, or if continuous casting follows the teeming, the ladle is brought to the continuous casting aisle and located over the tundish and teemed; or to the vacuum degasser for removal of hydrogen and oxygen gases in the molten steel. The slag pot receives the slag from the BOF and is moved to the slag dump yard.
2. Input Materials - Molten iron, scrap, fluxes, oxygen and alloying agents are used. A hot metal to scrap ratio of 3.4 to 1 has been used,¹ but varies from shop to shop dependent on availability of hot metal or scrap. Basically, the iron contains 0.2 to 2.0 percent silicon, 0.4 to 2.5 percent manganese, and up to 0.4 percent phosphorus.¹
3. Operating Parameters - The BOF process is exothermic and no additional heat is required. Refining occurs at approximately 2000°C at atmospheric pressure.
4. Utilities - Steelmaking with the basic oxygen furnace may require only 50 minutes, compared to 8 to 12 hours for the open-hearth furnace

with the same tonnage.¹ Electricity is required for the oxygen plant, vent gas fans, conveyors, furnace tilt mechanism, and other equipment.

5. Waste Streams - Particulate emission rates are so high that all basic oxygen units utilize high-efficiency particulate control devices. About 23 kilograms of particulate are produced per ton* of product, and about 0.1 kilogram of gaseous fluorides per ton.* Most of the furnace emissions are controlled by either venturi scrubbers or electrostatic precipitators.²

Table 43 gives the chemical composition of dust of three basic oxygen furnaces.³

The dust particles oxidize further outside the furnace vessels and produce fine red dust, whose size distribution is given in Table 44.⁴ Operation of basic oxygen furnaces may cause emission of flaking black material called "kish". Kish forms spontaneously whenever hot metal with carbon content greater than 4.5 percent is cooled below the liquid temperature. This results in the formation of solid Fe_3C , which is unstable and decomposes into graphite and iron.⁵ Usually the kish is formed when the hot metal is transferred into and out of the ladle.

Gas effluents ranging from 944,000 to 570,000 liters/sec are emitted from the basic oxygen furnace at temperatures between 1600 and 1900°C. These gases carry 140 kilograms or more of oxide dust per minute. Most of the dust is very finely divided, the particles ranging in size from 0.1 to 1 micron.⁶ About 20 to 30 kilograms of Fe_2O_3 are ordinarily collected per ton of steel produced.⁷ Table 45 gives the calculated composition of gases leaving the furnace on the basis that there is 100 percent of blown oxygen converted to carbon monoxide.⁸

Treatment of wastewaters from steelmaking by the basic oxygen process requires use of chemical coagulants or similar methods, which seldom can remove all particulate matter. Magnetic agglomeration has proved to be particularly effective in treating BOF wastewaters.⁹

6. EPA Source Classification Code - BOF General - 3-03-009-03.

* Metric tons (1000 kg)

Table 43. CHEMICAL COMPOSITION OF BASIC OXYGEN FURNACE STEELMAKING
DUST FROM THREE U.S. PLANTS, WEIGHT PERCENT

Element or compound	Typical	BOF dust from U.S. plants		
FeO	1.5	N.A.	N.A.	N.A.
Fe ₂ O ₃	90.0	80.00	N.A.	N.A.
Fe	N.A.	N.A.	56.0	57.68
Mn ₃ O ₄	4.4	N.A.	N.A.	N.A.
Mn	N.A.	0.35	1.2	1.54
SiO ₂	1.25	2.00	1.9	1.29
Al ₂ O ₃	0.2	0.15	0.4	0.13
CaO	0.4	5.10	3.1	3.59
MgO	0.05	1.10	N.A.	0.63
S	N.A.	0.12	0.09	0.12
P	N.A.	0.10	0.2	0.09
P ₂ O ₅	0.03	N.A.	N.A.	N.A.
Cu	N.A.	0.04	0.03	N.A.
Zn	N.A.	trace	1.93 ^a	4.80 ^a

Note: N.A. - data not available

^a The high zinc content in the dust is due to the use of galvanized steel scrap in the BOF charge.

Table 44. PARTICLE SIZE DISTRIBUTION OF RED DUST FROM
BASIC OXYGEN FURNACES

Size of particle	Percent
Smaller than 400 mesh	74
From 140 to 400 mesh	10
From 40 to 140 mesh	15
Larger than 40 mesh	1

About 40 percent of dust is smaller than 5 microns and 20 percent is less than 2 microns.

Table 45. CALCULATED GAS COMPOSITION FOR 91-TON BOF
BLOWN AT 6000 LITERS/SEC. (12,000 SCFM) O₂ RATE FOR 20 MINUTES

	Converter emissions			Peak gas flow rates after combustion, l/sec (Std.)	
	Total heat		Peak rate l/sec	Tight hood (10% combustion)	Open hood (20% excess air)
	kg	liters			
CO	5,400	456,000	11,300	10,000	0
CO ₂	1,300	167,000	0	11,300	11,300
O ₂	-	-	-	0	1,100
N ₂	-	-	-	2,100	25,600
Total	6,700	623,000	11,300	23,400	38,000

Metric tons

7. References -

1. The Pneumatic Steelmaking Processes. In: The Making, Shaping and Treating of Steel, Ninth Edition, McGannon, H. E. (ed.). Pittsburgh, Pennsylvania, U.S. Steel Company, 1971. p. 473-497.
2. Iron and Steel Mills. In: Compilation of Air Pollution Emission Factors. Environmental Protection Agency Contract Number CPA-22-69-119. April 1973. p. 7.5-5.
3. Varga, J. Jr., and H. W. Lownie. Emission Characteristics. Appendix C. In: Final Technological Report on A Systems Analysis Study of the Integrated Iron and Steel Industry, Battelle Memorial Institute, Columbus, Ohio. Contract Number PH-22-68-65. Department of Health, Education and Welfare. May 15, 1969. C-78 p.
4. Henschen, H. C. Wet vs Dry Gas Cleaning in the Steel Industry. Journal of Air Pollution Control Association. p. 338-342, May, 1968.
5. Haltgram, R. Fundamentals of Physical Metallurgy, New York, Prentice Hall, 1952.
6. Parker, C. M. BOP Air Cleaning Experiences. Journal of the Air Pollution Control Association. August 1966. p. 446-448.
7. Wheeler, D. H. The Iron and Steel Industry. In: Proceedings of the Electrostatic Precipitator Symposium. Sponsored by the Division of Process Control Engineering, Air Pollution Control Office, Environmental Protection Agency. February 23-25, 1971.
8. Industrial Gas Cleaning Institute, Inc. Air Pollution Control Technology and Costs in Nine Selected Areas. Environmental Protection Agency, Contract No. 68-02-0301. September 1972.
9. Bramer, H. C. Pollution Control in the Steel Industry. Environmental Science and Technology. 1004-1008, October 1971.

Vacuum Degassing

1. Function - In the steelmaking process the liquid steel may absorb gases, particularly hydrogen, from the atmosphere and from raw materials. Oxygen and nitrogen combine with alloying elements to form oxides, cyanonitride, or nitride compounds. All of these impurities are partially removed by vacuum degassing, which is done by three methods: stream degassing, circulation degassing, and ladle degassing. The effectiveness of any vacuum degassing process depends upon the surface area of liquid steel exposed to low pressure. Because the degassing operation reduces the temperature of liquid steel, it is necessary to carry out the operation at temperatures higher than the normal tapping temperature. The molten degassed steel is either continuously cast into slabs or billets or is cast into ingots for subsequent forming.
2. Input Material - Molten steel is the only input material. Alloying additives are added after degassing.
3. Operating Parameters - In the stream degassing method the tank is evacuated to a absolute pressure of 0.05 to 0.500 mm Hg. In this method the liquid steel is tapped with 10 to 55°C superheat. In the induction stirred ladle degassing method the liquid steel, with 21 to 66°C superheat is exposed to pressures ranging from 0.075 to 0.200 mm Hg, depending upon the grade of steel. The steel to be degassed by the recirculation degassing method is superheated from 20 to 80°C above the tapping temperature and the pressure in the vessel gradually decreases to the range of 300 to 600 microns.¹
4. Utilities - No data available.
5. Waste Streams - About 5 kilograms of particulate are emitted from degassing a 100-ton* heat (charge). Composition of the dust that settles in the vacuum chamber depends on the alloying elements in the steel and their respective vapor pressures. Analysis of dust generated during vacuum degassing, and analysis of the metal in the ladle after treatment are given in Table 46.

* Metric tons (1000 kg)

Table 46. DUST AND METAL ANALYSES FOR VACUUM-TREATED STEELS

Material	Elements, weight percent								
	C	Mn	Si	Ni	Cr	V	Mo	Cu	Fe
Steel in ladle	0.33	0.73	0.25	2.86	0.99	0.22	0.53	0.17	-
Dust	1.66	46.30	1.63	0.38	0.36	0.01	0.03	1.60	17.60
Steel in ladle	0.33	0.83	0.26	0.17	1.01	0.23	1.21	0.14	-
Dust	1.69	47.70	1.40	0.13	0.38	0.04	0.09	1.20	15.50

The composition of off-gases from stream degassing, which varies with grade of steel and extent of the vacuum treatment, can range from 18 to 50 percent carbon monoxide, 20 to 70 percent hydrogen, negligible amounts to 30 percent water, 1 to 20 percent oxygen, 15 to 75 percent nitrogen, and 1 to 6 percent carbon dioxide. The composition of off-gases from recirculation degassing is up to 80 percent carbon monoxide, up to 20 percent carbon dioxide, and up to 15 percent hydrogen.²

6. EPA Source Classification Code - None exists.

7. References -

1. The Making, Shaping and Treating of Steel. Ninth Edition. McGannon, H.E. (ed.). Pittsburgh, Pennsylvania, U.S. Steel Company. 1971.
2. Varga, J. Jr., and H. W. Lownie. Emission Characteristics. Appendix C. In: Final Technological Report on A Systems Analysis Study of the Integrated Iron and Steel Industry. Battelle Memorial Institute, Columbus, Ohio. Contract Number PH-22-68-65. Department of Health, Education and Welfare. May 1969. C97-C121 p.

Continuous Casting or Ingot Castings

1. Function - The molten steel (degassed or not) either is cast continuously into products of the desired shape or is cast into ingots for subsequent forming.

In continuous casting process a ladle of steel is brought and positioned over the tundish which is over the water cooled copper mold. The ladle nozzle is opened and the tundish is filled with molten steel to the desired depth. Then the tundish nozzles are opened to permit molten steel to enter the molds. The casted strand passes through a cooling chamber, straightening mechanism, and cutting device where it is cut into the desired lengths.

In conventional ingot making the molten steel is tapped into a refractory lined steel ladle. The ladle is moved by an overhead crane to a pouring platform where the steel is then teamed into a series of molds of the desired dimensions. Alloying materials and deoxidizers may be added during the tapping of the charge or in the molds. The steel solidifies in each of the molds to form a casting called ingot.¹

2. Input Materials - Molten steel.
3. Operating Parameters - None exists.
4. Utilities - No data available.
5. Waste Streams - Continuous casting and ingot making contributes very little to air pollution.
6. EPA Source Classification Code - None exists.
7. References -

1. The Making, Shaping and Treating of Steel. Ninth Edition. McGannon, H.E. (ed.). Pittsburgh, Pennsylvania, U.S. Steel Company. 1971.

Rolling and Shaping

1. Function - The temperature of steel ingots are raised in a soaking pit furnace to prepare it for hot working (rolling). In the furnace the steel is heated until it is plastic enough for rolling to desired shape. After the ingots are rolled into billets, blooms, or slabs, they are cooled and inspected. Surface defects are removed by grinding, chipping, peeling, or scarfing. Reheating furnaces are used for raising temperature of slabs, blooms, or billets for rolling into sheets, coils, or other shapes.
2. Material of construction - Ingots.
3. Operating Parameters - Soaking pits may have a hearth area of 10 to 30 square meters. Hearth areas of reheating furnaces range from a few square meters to 400 square meters. The normal temperature range for heating ingots is between 1180 and 1340°C.
4. Utilities - Furnaces are fired with either blast furnace gas, coke-oven gas, natural gas, fuel oil or a mixture. Consumption of fuel per ton* of steel varies from approximately 111,100 to 555,600 kilocalories, depending on the temperature of the charged steel.¹ Water consumption in rolling or shaping operations ranges from 7600 to 26,500 liters per minute.² Table 47 indicates the range of power consumption in rolling or shaping mills.¹
5. Waste Streams - Data is not available on the emissions that occur during charging and removing of ingots, or during firing. Particulate emissions are considered to be negligible, unless the pits are fired with fuel other than gas. During breakdown of the ingots by rolling into billets, blooms or slabs, there can be some emission of steam, which is confined in the building. Grinding and chipping generate particulates which are confined in a building adjacent to this area. Airborne particles released from scarfing are extremely fine.

Table 47. POWER CONSUMPTION IN ROLLING OR SHAPING MILLS**

Operating unit	kWh consumed per ton* of product
Blooming mill	13-5, based on blooms
Slabbing mill	10-12, based on slabs
Plate mill	30-40, based on plates
Merchant mills	40-80, based on product
Wide strip mill	45-65, based on product

* Metric tons (1000 kg)

** Covers the power used by the main drive motors, and does not include that used for auxiliaries such as table, fan, etc.

Loss of metal is from 3 to 6 percent in scarfing of billets, up to 2.5 percent in scarfing of slabs, and up to 7 percent for blooms. Losses of gas in scarfing of slabs range from 0.46 to 10 grams per cubic meter. Many scarfing operations control particulate emissions with fabric filters. Emissions during reheating of steel billets and slabs are mixtures of carbon monoxide, carbon dioxide, nitrogen and moisture from the combustion of natural gas.³

Typical large rolling mill wastes are shown in Table 48.⁴

Table 48. QUANTITIES OF SOLID AND WATER WASTE FROM TYPICAL ROLLING MILL (IRON AND STEEL INDUSTRY)

Mill	Solids load, kg/ton* of product from each processing	Waste water, l/ton*
Slab	15.00	3,000
Hot-strip	25.00	25,000
Blooming	9.50	10,000
30" billet	14.60	6,000
21" billet	14.60	6,000
Hot scarfer	25.00	5,000

The steel mill wash waters may contain from 1000 to 2000 milligrams suspended solids per liter. The metal composition of suspended solids roughly reflects the furnace charge.⁵

Most scale and oil produced in rolling mills are recovered in crude settling chambers called scale pits.⁶

6. EPA Source Classification Code - None exists.

Finishing/Soaking Pits - 3-03-009-11.

7. References -

1. The Making, Shaping and Treating of Steel. Ninth Edition. McGannon, H.E. (ed.). Pittsburgh, Pennsylvania, U.S. Steel Company, 1971.

2. Bramer, H.C. Iron and Steel. Chapter 14. In: Industrial Waste Water Control, Chemical Technology, A Series of Monographs - Volume 2, New York, Academic Press, 1965.
3. Varga, L. Jr., and H. W. Lownie. Final Technological Report on A Systems Analysis Study of the Integrated Iron and Steel Industry, Gurnham, C.F. (ed.). Battelle Memorial Institute, Columbus, Ohio. May 1969.
4. Industrial Waste Profiles No. 1 - Blast Furnace and Steel Mills. Volume III. In: The Cost of Clean Water. Federal Water Pollution Control Administration. FWPCA Contract Number 14-12-98. September 28, 1967.
5. Sittig, M. Iron. In: Pollutant Removal Handbook. New Jersey, Noyes Data Corporation, 1973. p. 251-257.
6. Bramer, H. C. Pollution Control in the Steel Industry. Environmental Science and Technology. 1004-1008, October 1971.

Acid Treatment (Pickling)

1. Function - The oxidized surface of the hot-rolled steel is cleaned by acid treatment (pickling) in preparation for cold rolling.¹ The metal is then rinsed with water to remove the bulk of the contaminants from the pickled product.

2. Input Materials - Sulfuric acid or hydrochloric acid is used for pickling. Consumption of acid varies over a wide range from a low of about 0.5 kilogram per ton* to a high of about 25 kilograms per ton*. The volume of water used for rinsing is in the range of about 200 to 400 liters per ton* of steel pickled.²

3. Operating Parameters - No data available.

4. Utilities - No data available.

5. Waste Streams - Acid fumes occur during pickling.³ Water discharge from the pickling operation generally includes spent strong pickle liquor and the acidic rinse water, which must be neutralized before it can be safely discharged. An estimated 150,000 tons of pollutants are expected from pickling processes in 1975. A typical pickling process produces waste water containing 2.25 kilograms of free acid and 8.4 kilograms of combined acid per ton* of ingot.⁴

Iron concentration in waste pickle liquor is about 70,000 milligrams per liter.⁵ Spent pickling solutions and acid rinse waters differ widely in quantity, composition, and concentration. Acid rinse waters have the same relative proportions of iron salts and free acid pickling solution, but are much more diluted. 10 to 15 percent of acid used in pickling is discharged in rinse waters. Spent sulfuric acid pickling solutions contain free acid, ferrous sulfate, undissolved scale and dirt, and trace metals. Spent sulfate pickling solutions are discharged at 30 to 90°C.⁶ Pickling tanks emit pungent and corrosive mist and vapor.

Potential liquid waste streams, other than spent pickle liquor, are suspended particles of waterborne scale, lubricating oil, and pickling rinse water.⁷

* Metric tons (1000 kg)

Strong pickle liquors and rinse waters are often neutralized with lime. Sludge resulting from lime neutralization of spent pickle liquor is a principal solid waste problem. Lagoons filled with the material, which never dries, constitute a major problem at many mills.⁷

6. EPA Source Classification Code -

Finishing/Pickling - 3-03-009-10

7. References -

1. The Making, Shaping and Treating of Steel. Ninth Edition. McGannon, H.E. (ed.). Pittsburgh, Pennsylvania, U.S. Steel Company, 1971.
2. Kemmer, F.N. Pollution Control in the Steel Industry. In: Industrial Pollution Control Handbook, Lund, H.F. (ed.). New York, McGraw-Hill Book Company, 1971. p. 16.
3. Varga, L. Jr., and H.W. Lownie. Final Technological Report on a Systems Analysis Study of the Integrated Iron and Steel Industry, Furnham, C.F. (ed.). Battelle, Memorial Institute, Columbus, Ohio. May 1969.
4. Ralph Stone and Company, Inc. Forecasts of the Effects of Air and Water Pollution Controls on Solid Waste Generation. National Environmental Research Center. Publication Number PB-238-219. December 1974.
5. Sittig, M. Iron. In: Pollutant Removal Handbook. New Jersey, Noyes Data Corporation, 1973. p. 251-257.
6. Bramer, H.C. Iron and Steel. Chapter 14. In: Industrial Waste Water Control, Chemical Technology, A Series of Monographs - Volume 2, New York, Academic Press, 1965.
7. Bramer, H.C. Pollution Control in the Steel Industry. Environmental Science and Technology. 1004-1008, October 1971.

Finishing

1. Function - Finishing operations primarily consist of treating the semifinished steel products of costs, plates, billets, blooms by hot or cold working and processing to the final form. Some of the sheet and tin finishing operations are: tempering, tin plating, galvanizing, chrome plating, coating, polishing, continuous annealing. Other finishing operations concern tube or pipe mills, bars, wires, and rails; and their treatment. Treatment may include rolling, piercing, reheating, welding, pickling, washing and plating.
2. Input Materials - Steel is the primary input material.
3. Operation Parameters - No data available.
4. Utilities - Some power requirements are 95 to 110 kWh per ton* for 5 stand cold reduction mill, 42 kWh per ton* for tinning operations and 33 kWh per ton for sheet-mill galvanizing.¹
5. Waste Streams - Solid waste is evolved from internally generated scrap and as a result of tank cleanouts or precipitates from wastewater treatments. Scrap is essentially all reused, but can result in wastewater treatments. Essentially all scrap is reused, but can result in wastewater problems in reclaiming operations. Emulsified oil from cold rolling presents a difficult wastewater treatment problem.² New tin plating plants produce an estimated 0.073 liters of wastewater, 0.032 kilograms of chromium and 0.008 kilograms of tin per ton* of steel ingot. Galvanizing plants are estimated to produce 0.018 liters of wastewater containing 0.0013 kilograms of zinc per ton* of steel ingot.³

EPA Source Classification Data - Finishing/other - 3-03-009-20.

7. References -

1. The Making, Shaping and Treating of Steel, Ninth Edition, McGannon, H.E. (ed.). Pittsburgh, Pennsylvania, U.S. Steel Company, 1971
2. Kulujian, N.J. Compliance Status Evaluation of Iron and Steel Facilities in New York. PEDCo-Environmental Specialists, Inc. Contract Number 68-02-1321. Environmental Protection Agency. April 1975.

* Metric ton (1000 kg)

2. Bramer, H. C. Pollution Control in the Steel Industry. Environmental Science and Technology. 1004-1008, October 1971.
3. Industrial Waste Profiles No. 1 - Blast Furnace and Steel Mills. Volume III. The Cost of Clean Water. Federal Water Pollution Control Administration. FWPCA Contract Number 14-12-98. September 28, 1967.

APPENDIX A

RAW MATERIALS

Table A-1. IRON ORE MINED IN THE UNITED STATES¹

District	Type of ore	Approximate percent of total tonnage mined
Lake Superior	Hematite	48
Birmingham, Alabama	Hematite brown	7
Chattanooga, Tennessee	Brown	1
Adirondack, Northern New York	Magnetite	4
Northern new Jersey and South Eastern New York	Magnetite	1
Lone Star, Texas		
Iron Mountain, Missouri	Hematite	
Vulcan, California	Brown	
Cornwall, Pennsylvania	Magnetite	
Sunrise, Wyoming	Carbonate	
Iron County, Utah		

Table A-2. CONSUMPTION OF MATERIALS OTHER THAN IRON ORE IN
IRON AND STEEL INDUSTRY - 1973²

Major material	Quantity
Fluorspar	0.561 million tons*
Limestone	21.80 million tons*
Lime	7.080 million tons*
Other fluxes	0.820 million tons*
Oxygen	6092. billion liters*
Coal:	
In production of coke	77.64 million tons*
In production of steam ^a	3.81 million tons*
Other purposes	0.53 million tons*

^aIncludes coal consumed in generating electric power.

*Metric tons (1000 kg)

Table A-3. ORIGIN OF COAL RECEIVED BY COKE-OVEN PLANTS IN THE UNITED STATES IN 1974 BY PRODUCING STATE AND VOLATILE CONTENT^{a,3}

Source of coal ^b	Volatile content			Total
	High	Medium	Low	
Alabama	2,488	3,955	-	6,443
Arkansas	-	-	178	178
Colorado	1,554	399	486	2,439
Illinois	4,035	-	-	4,035
Kentucky	14,564	-	-	14,564
Maryland	-	-	7	7
New Mexico	925	-	-	925
Ohio	41	-	-	41
Oaklahoma	165	175	3	343
Pennsylvania	18,588	1,103	5,172	24,863
Tennessee	169	-	-	169
Utah	1,863	-	-	1,863
Virginia	1,744	1,065	1,748	4,557
West Virginia	14,262	2,886	9,558	26,706
Total	60,398	9,583	17,152	87,133

^a Volatile matter on moisture - free basis; high-volatile - over 31 percent; medium-volatile - 22 to 31 percent; and low-volatile - 14 to 22 percent.

^b Cumulative of individual county production in the state

Table A-4. ANALYSIS OF LIMESTONE FROM COLUMBUS, OHIO ⁴

Constituent	Percent
SiO ₂	0.06
Al ₂ O ₃	0.04
CaO	30.83
MgO	22.27
P	-
S	0.020

APPENDIX B

INDUSTRY PRODUCTS

Table B-1. AVERAGE GRADE OF SINTER PRODUCED IN 1968
NORTHEASTERN IRON ORES (Wt. %, DRY BASIS)⁵

	Fe	P	SiO ₂	Mn	Al ₂ O ₃	CaO	MgO	S
Benson sinter	63.91	0.026	5.47	0.30	3.02	1.39	0.26	0.030
Benson Non-Bessemer sinter	62.60	0.199	4.31	0.16	2.74	1.28	0.26	0.030
Port Henry sinter	66.17	0.140	3.94		1.22	1.16	0.26	

Table B-2. TYPICAL TACONITE CONCENTRATE PRODUCT ANALYSIS⁶

Composition	Percentage
Fe	64.55
SiO ₂	9.2
CaO	0.53
MgO	0.67
Al ₂ O ₃	0.55
Mn	0.22

Table B-3. COMPOSITIONS OF PELLETS PRODUCED IN 1968, (Wt. %, DRY BASIS)^a

	Fe	P	SiO ₂	Mn	Al ₂ O ₃	CaO	MgO	S
Minntae ^a pellets	65.12	0.011	5.50	0.16	0.42	0.25	0.59	0.002
Reserve ^a pellets	62.55	0.028	8.76	0.27	0.47	0.44	0.51	
Erie ^a pellets	63.91	0.012	7.22	0.23	0.31			
Eveleth ^a pellets	65.39	0.012	5.50	0.14	0.29	0.19	0.30	
Birch Lake ^a pellets	62.48	0.023	9.00	0.22	0.54	0.50	0.65	
Cornwell pellets	64.92	0.006	3.30	0.08	1.50	0.90	1.50	0.009
Morgantown pellets (Grace Mine)	65.83	0.010	3.18	0.08	0.61	0.55	1.54	0.009

^a Pellets produced from concentrates originated with magnetic taconites.

Table B-4. CHEMICAL ANALYSIS OF NODULIZED PRODUCT, AVERAGE^{a,7}

Composition	Percent
Moisture	0.12
Fe	62.99
SiO ₂	7.33
Mn	0.29
P	0.020
CaO	2.44

^a Taconite concentrate is used as input to the kiln.

Table B-5. SUMMARY OF THE COKE INDUSTRY
IN THE UNITED STATES IN 1974⁸

Material	Quantity
Coke produced:	
At merchant plants	4,632,000 tons*
At furnace plants	50,466,000 tons*
Total	55,865,000 ^a tons*
Coke breeze produced	4,621,000 tons*
Coal carbonized:	
Bituminous	81,420,000 tons*
Anthracite	403,000 tons*
Average yield of coke of total coal carbonized, %	68.28
Coke used in blast furnaces	51,200,000 tons*
Coke breeze used in agglomerating plants	1,334,000
Coal chemical materials produced:	
Crude tar	2,564,137,000 liters
Ammonia	519,000 tons*
Crude light oil	822,920,000
Gas	27,392,000 x 10 ⁶ liters

^a About 1.4 percent of this amount is produced in beehive ovens.

* Metric tons (1000 kg)

Table B-6. TYPICAL SIZES OF COKE⁹

Variety of Coke	Size, cm
Foundry	Various sizes, >8
Blast furnace	8 x 0.75
Breeze	through 1.9

Table B-7. TYPICAL PROPERTIES OF COKE⁹

Moisture, %	2
Volatile matter, %	0.5 - 2
Fixed carbon, %	87 - 91
Ash, %	5 - 9
Heating value, kcal/kg	7050 - 7350

Table B-8. YIELDS AND ANALYSES OF PRODUCTS OF CARBONIZATION PROCESS^{10,11}

Product	Constituent	Percent of coal by weight	Analysis percent of product by weight	Yield kg per ton*
Coke	Ash	7.210	10.24	72.10
	Carbon	61.711	87.76	617.12
	Hydrogen	0.469	0.66	4.69
	Sulphur	0.683	0.96	6.83
	Nitrogen	0.270	0.38	2.70
	Totals	70.343	100.00	703.44
Gas	CO ₂	1.042	6.66	10.42
	CO	3.154	20.14	31.54
	CH ₄	7.468	47.69	74.68
	C ₂ H ₄	1.529	9.76	15.29
	N ₂	0.385	2.46	3.85
	H ₂	1.366	8.72	13.66
	O ₂	0.717	4.57	7.17
	Totals	15.661	100.00	156.61
Ammonia	Hydrogen	0.040	17.9	0.40
	Nitrogen	0.183	82.1	1.83
	Totals	0.223	100.0	2.23
Tar	Carbon	4.687	86.0	46.87
	Hydrogen	0.327	6.0	3.27
	Oxygen	0.436	8.0	4.36
	Totals	5.450	100.0	54.50
Liquor	Moisture	3.310	48.70	33.10
	Oxygen	3.107	45.60	31.07
	Hydrogen	0.388	5.70	3.88
	Totals	6.805	100.0	68.05
Light oils	C ₆ H ₆ (Equivalent)	1.102	100.0	11.02
Cyanogen	C ₂ N ₂	0.078	100.0	0.78
Carbon disulphide	CS ₂	0.013	100.0	0.13
Hydrogen sulphide	H ₂ S	0.325	100.0	3.25

* Metric ton (1000 kg)

Table B-9. COMPOSITION OF HIGH-TEMPERATURE¹²
COKE-OVEN TAR^a

	Percent by weight
Liquor	1.6-5.8
Benzol	0.1-0.3
Toluol	0.1-0.4
Xylol	0.1-0.5
Total tar acids (phenols, cresols, xylenols)	2.0-3.9
Total tar bases (pyridine, picolines, quinolines)	1.4-2.0
Naptha (coumarone, indene)	0.4-2.0
Crude naphthalene	7.7-11.7
Methylnaphthalene oil	2.1-2.9
Biphenyl oil	0.9-1.5
Acenaphthene oil	1.4-2.8
Fluorene oil (fluorene, diphenyl oxide)	1.9-3.6
Anthracene-heavy oil (anthracene, phenanthrene, carbazole)	9.6-12.3
Pitch	60.2-64.2
Distillation losses	0.9-2.8

^a Ranges of composition of five typical tars from "The Coal Tar Data Book." The Coal Tar Research Association, 2nd Ed., Section A1, 2-4, 1965.

Table B-10. ANALYSIS OF CRUDE AMMONIA LIQUOR¹³

Specific gravity	1.1055
Ammonia, total, percent	22.47
free, percent	22.20
Pyridine, grams per liter	2.79
Sulfides as H ₂ S, grams per liter	53.3
Organic matter, cc N/50 KMnO ₄ per liter	103,300

APPENDIX C

COMPANIES

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Table C-1. IRON AND STEEL PRODUCING FACILITIES¹⁴

Company - Plant	Location	No. of agglomerating facilities	No. of blast furnaces	Type of furnace	Steel producing		Size tons/heat	Coke production
					No. of furnaces	Steel grade		
Alan Wood Steel Coke and Chemical Plant Blast Furnaces Ivy Rock Plant	Conshohocken, Pa. Swedeland, Pa. Swedeland, Pa. Ivy Rock, Pa.	3	2	Basic Oxygen	2	Carbon, low alloy	150	Yes
				Hot blast cupola	1	Iron	55/hr	
				Basic O ₂ furnace	2	Alloy	80	
				Electric Arc	5	Alloy & stainless	80 (2) 70 (2) 55 (1)	
Allegheny Ludlum Ind., Inc. Allegheny Ludlum Steel Corp.	Pittsburgh, Pa.			Vacuum reduction	1	Refining stainless	80	
				Electric Arc	4	Carbon, alloy, & stainless	25 (2) 15 (1) 2 (1)	
				Vacuum melt induction	1	Stainless	1/5 or 1	
				Vacuum Melt electrode	7	Alloy & Stainless	1/2 to 11	
Ajax Forging & Casting Co.	Ferndale & Detroit Michigan			A.O.D. Vessel	1	Stainless	25	
				Electric Arc	2	Alloy	1 & 4	
				Induction	6	Alloy	1/4 to 2	
				Vacuum Melt induction	5	Specialty steels	15 (1) 6 (1) 0.5-2.5(3)	
New Hartford Works	New Hartford, N.Y.			Consumable electrode	8	Specialty Steels	5	

*Metric ton (1000 kg)

Table C-1 (continued). IRON AND STEEL PRODUCING FACILITIES¹⁴

Company - Plant	Location	No. of agglomerating facilities	No. of blast furnaces	Type of furnace	Steel production		Size concs/heat	Coke production
					No. of furnaces	Steel grade		
American Compressed Steel Corp.	Cincinnati, Ohio			Electric Arc	1	Carbon	6	
Ameron Steel Producing Div.	Etiwanda, Ca.			Electric Arc	3	Carbon, Alloy	15 & 18	
Armco Steel Corporation	Middletown, Ohio							
Ashland Works	Ashland, Ky.	1	2	Basic O ₂	2	Carbon, Alloy	180	
Butler Plant	Butler, Pa.			Electric Arc	3	Carbon, alloy stainless	165	
Hamilton Plant	Hamilton, Ohio		2					yes
Houston Works	Houston, Texas	1	1	Electric Arc	6	Carbon, alloy	117 (2) 175 (4)	yes
Kansas City Works	Kansas City, Mo.			Electric Arc	4	Carbon, Alloy	125 (2) 150 (2)	
Middletown Works	Middletown, Ohio		1	Basic Open Hearth	6	Carbon	310	yes
				Basic O ₂	2	Carbon	200	
Sand Springs Works	Sand Springs, Okla.			Electric Arc	2	Carbon	70	
Baltimore Works	Baltimore, Md.			Electric Arc	3	Superalloy, stainless	25 (2) 40.0 (1)	
				Vacuum Arc Re- melt	2	Superalloy, stainless	10	
				Ar-O ₂ Reactor	1	Superalloy, stainless	20/40	
Torrance Plant	Torrance, Ca.			Electric Arc	2	Carbon, alloy, stainless	22.5 (1) 10.0 (1)	

* Metric tons (1000 kg)

Table C-1 (continued). IRON AND STEEL PRODUCING FACILITIES¹⁴

Company - Plant	Location	No. of agglomerating facilities	No. of blast furnaces	Type of furnace	Steel production		Size tons/heat	Coke production
					No. of furnaces	Steel grade		
<u>Atlantic Steel Company</u> <u>Babcock & Wilcox Co.</u>	Atlanta, Ga.			Electric Arc	2	Carbon	85	
	Beaver Falls, Pa.			Electric Arc	9	Carbon, alloy stainless	25 (2) 50 (2) 75 (2) 100 (3)	
<u>Bethlehem Steel Corp.</u> <u>Bethlehem Plant</u>				Argon Oxygen	1	Stainless	25	
	Bethlehem, Pa.			Electroslag remelt		Stainless & high alloy	3	
	Bethlehem, Pa.	4 ^a	4	Basic oxygen	2	Carbon, alloy	270	Yes
Steelton Plant	Steelton, Pa.			Electric Arc	6	Alloy	7 (1) 28 (1) 50 (4)	
				Electric Arc	5	Carbon, alloy	5 (1) 15 (1) 150 (3)	
Sparrows Point Plant	Sparrows Pt. Md.	6 ^a	10	Open hearth furnaces	7	Carbon, alloy	420	Yes
				Basic O ₂	2	Carbon, alloy	220	
Lackawanna Plant	Lackawanna, N.Y.	6 ^a	6	Basic open hearth	8	Carbon, alloy	190 (3) 190 (5)	Yes
				Basic oxygen	3	Carbon, alloy	300	
Johnstown Plant		2 ^a	4	Basic open hearth	8	Carbon, alloy	180	Yes

^a No. of strands.

* Metric tons (1000 kg)

Table C-1(continued). IRON AND STEEL PRODUCING FACILITIES¹⁴

Company - Plant	Location	No. of agglomerating facilities	No. of blast furnaces	Type of furnace	Steel production		Size tons*/heat	Coke production
					No. of furnaces	Steel grade		
Burns Harbor Plant	Westchester Twp., Ind.		2	Basic oxygen	2	Carbon, alloy	300	Yes
Los Angeles Plant	Los Angeles, Ca.		3	Electric Arc	3	Carbon, alloy	75 (1) 100 (2)	
Seattle Plant	Seattle, Wash.			Electric Arc	2	Carbon, alloy	120	
Morgantown Plant	Morgantown, Pa.	6						
Border Steel Rolling Mills, Inc.	El Paso, Texas			Electric Arc	2	Carbon, low alloy	25	
Borg-Warner Corporation	Chicago, Ill.							
Chicago Heights Works	Chicago Hts, Ill.			Electric Arc	2	Carbon	30	
New Castle Works	New Castle, Ind.			Electric Arc	4	Carbon, alloy stainless	9 (2) 12 (2)	
Braeburn Alloy Steel Div.	Braeburn, Pa.							
Braeburn Works	Braeburn, Pa.			Electric Arc	2	Carbon, alloy	10	
				Vacuum consumable electrode arc remelt	1		11	
Cabot Corporation	Boston, Mass.							
Machinery Division at Pampa	Pampa, Texas			Electric Arc	1	Alloy	10	

* Metric tons (1000 kg)

Table C-1(continued). IRON AND STEEL PRODUCING FACILITIES¹⁴

Company - Plant	Location	No. of agglomerating facilities	No. of blast furnaces	Type of furnace	Steel production		Steel tonnes/heat	Coke production
					No. of furnaces	Steel grade		
<u>Cameron Iron Works, Inc.</u>	Houston, Texas			Electric Arc	1	Carbon, alloy	60	
				Vacuum Induction	2	Specialty alloys	25 & 60	
				Vacuum consumable	20	Specialty alloys	16 - 34	
<u>Carpenter Technology Corp.</u> Carpenter Steel Div. - Reading	Reading, Pa.			Electric Arc	5	Alloy, stainless	14	
				Vacuum induction	2	Alloy, stainless	7.5 (1) 7.5 (1)	
				Consumable elect.	10	Alloy, stainless	2.5 (2) 4 (2) 9 (6)	
				Electroslag remelt	2	Alloy, stainless	15	
Bridgeport Plant	Bridgeport, Conn.			Argon-oxygen decarb.	1	Alloy, stainless	15	
				Electric Arc	2	Alloy, stainless	42	
				Ar - O ₂ Decarb.	1	Alloy, stainless	50	
<u>Caco Corp. (The)</u> Lemont Works Milton Works Birmingham Works	Chicago, Ill.			Electric Arc	3	Carbon	30	
	Lemont, Ill.			Electric Arc	3	Carbon	20	
	Milton, Pa.			Electric Arc	2	Carbon, high strength, low alloy	14	
	Birmingham, Ala.			Electric Arc	2	Carbon, high strength, low alloy	14	

* Metric tons (1000 kg)

Table C-1(continued). IRON AND STEEL PRODUCING FACILITIES¹⁴

Company - Plant	Location	No. of agglomerating facilities	No. of blast furnaces	Type of furnace	Steel production		Size tons*/heat	Coke production
					No. of furnaces	Steel grade		
CF & I Steel Corporation								
Pueblo Plant	Pueblo, Colo.	1	4	Basic oxygen	2	Carbon, alloy	118	Yes
	Pueblo, Colo.			Electric Arc	1	Carbon, alloy	120	
				Electric Arc	3	Carbon	43	
Roebbing Plant	Roebbing, N.J.							
Columbia Tool Steel Co.	Chicago Hts., Ill.			Electric Arc	2	Tool steel	5 (1) 8 (1)	
Chicago Heights Works	Chicago Hts., Ill.							
Continental Steel Corp.	Kokomo, Ind.			Electric Arc	2	Carbon	175	
Kokomo Works	Kokomo, Ind.							
Copperweld Corporation	Pittsburgh, Pa.			Electric Arc	7	Carbon, alloy	45 (3) 75 (4)	
Copperweld Specialty Steel Co.	Warren, Ohio							
Crucible Inc. (subsidiary of Cott Industries)	Pittsburgh, Pa.			Top oxygen				
Alloy Division	Midland, Pa.		2	Top oxygen converters	2	Carbon, alloy	100	Yes
				Electric Arc	5	Carbon, alloy, stainless	75 (4) 25 (1)	
Stainless Steel Div.	Midland, Pa.			AOD Refining	1	Stainless	100	
				Electrode vacuum	9	Alloy, stainless	10 (4) 2.5 (1) 10 (2) 4 (1) 2.5 (1)	

* Metric tons (1000 kg)

Table C-1(continued). IRON AND STEEL PRODUCING FACILITIES¹⁴

Company - Plant	Location	No. of agglomerating facilities	No. of blast furnaces	Type of furnace	Steel production		Size tons/heat	Coke production
					No. of furnaces	Steel grade		
Specialty Metals Div.	Syracuse, N.Y.			Curved-mold cont.	1	Stainless	100	
				Electric Arc	5	Carbon, alloy, stainless	35 (1) 15 (4)	
				Electric Induction	1	Carbon, alloy, stainless	1	
				Vacuum melting Induction		Alloy, stainless	1.5	
Cyclops Corporation Empire Detroit Steel Div. (Mansfield Plant)	Pittsburgh, Pa. Mansfield, Ohio			Vacuum melting electrode arc remelting		Alloy, stainless	10	
				Basic open hearth	5	Carbon, alloy	170	
				Electric Arc	2	Carbon, alloy, stainless	100	
				AOD Refining vessel	1	Alloy, stainless	100	
Portsmouth Division	Portsmouth, Ohio		2	Basic open hearth	5	Carbon	320	Yes
Bridgeville Plant	Bridgeville, Pa.			Electric Arc	3	Stainless & specialty	40 (1) 20 (2)	
				Vacuum arc remelt	2	Specialty grades	6	
				Vacuum Induction	1	Specialty grades	1.7	
				Electroslag re-fining	1	Specialty grades	4	

* Metric tons (1000 kg)

Table C-1(continued). IRON AND STEEL PRODUCING FACILITIES¹⁴

Company - Plant	Location	No. of agglomerating facilities	No. of blast furnaces	Type of furnace	Steel production		Size tons/heat	Coke production
					No. of furnaces	Steel grade		
<u>Donner-Hanna Coke Corp.</u>	Buffalo, N.Y.							
<u>Eastern Stainless Steel Co.</u>	Baltimore, Md.			Electric Induction	2	Alloy & stainless	3 1/4	
<u>Baltimore Works</u>	Baltimore, Md.			Electric arc	3	Alloy & stainless	15 (2) 50 (1)	
<u>Electralloy Corp.</u>	New York, N.Y.			Electric Arc	1		35	
<u>Oil City Works</u>	Oil City, Pa.			Ar-O ₂ vessel	2		20 (1) 30 (1)	
				Vacuum Induction	1		3	
				Electric Induction	2		.75 (1) .25 (1)	
				Gas fired	2		18 (1) 50 (1)	
<u>Elliott Bros. Steel Co.</u>	New Castle, Pa.							
<u>Florida Steel Corp.</u>	Tampa, Fla.			Electric Arc	3	Carbon	20 (1) 25 (1) 35 (1)	
<u>Tampa Works</u>	Tampa, Fla.			Electric Arc	2	Carbon	30 (1) 35 (1)	
<u>Indiantown Works</u>	Indiantown, Fla.			Electric Arc	2	Carbon	25 (1) 30 (1)	
<u>Croft Works</u>	Croft, W.C.			Electric Arc	2	Carbon		

* Metric tons (1000 kg)

Table C-1(continued). IRON AND STEEL PRODUCING FACILITIES¹⁴

Company - Plant	Location	No. of agglomerating facilities	No. of blast furnaces	Type of furnace	Steel production		Size tons#/heat	Coke production
					No. of furnaces	Steel grade		
<u>Ford Motor Company</u>								
Rouge Works	Dearborn, Mich.		3	Basic oxygen	2	Carbon, alloy	240	Yes
<u>Georgetown Steel Corp.</u>	Dearborn, Mich.			Electric Arc	3	Carbon	65	
<u>Harrisburg Steel Co.</u> (Div. of Harsco Corp.)	Georgetown, S.C.							
Harrisburg Works	Harrisburg, Pa.			Basic open hearth	3	Carbon, alloy	50	
<u>Hawaiian Western Steel Limited</u>	Harrisburg, Pa.							
Ewa Works	Ewa, Hawaii			Electric Arc	1	Carbon	15	
<u>Heppenstall Company</u>	Pittsburgh							
Nidvale - Heppenstall Co.	Philadelphia, Pa.			Electric Arc	3	Carbon, alloy, stainless	40 (1) 80 (1) 140 (1)	
<u>Industrial Products Group</u>				Vacuum electrode	3	Carbon, alloy, stainless	5 (2) 55 (1)	
Coke Plant	Woodward, Ala.							Yes
Chattanooga Div.	Woodward, Ala.							Yes
	Chattanooga, Tenn.							

* Metric tons (1000 kg)

Table C-1(continued). IRON AND STEEL PRODUCING FACILITIES¹⁴

Company - Plant	Location	No. of agglomerating facilities	No. of blast furnaces	Type of furnace	Steel production		Size tons#/heat	Coke production
					No. of furnaces	Steel grade		
<u>Inland Steel Co.</u>	Chicago, Ill.	1	8	Basic open hearth	19	Carbon, alloy	210 (12)	Yes
Indiana Harbor Works	East Chicago, Ill.			Basic oxygen	4	Carbon, alloy	335 (7)	
				Electric arc	2	Carbon, alloy	255 (2) 210 (2) 120	
<u>Interlake Incorporated</u>	Chicago, Ill.		2					Yes
Chicago Plant	South Chicago, Ill.		1					Yes
Erie Plant	Erie, Pa.		2					Yes
Toledo Plant	Toledo, Ohio							Yes
Riverdale Station Works	Chicago, Ill.			Basic oxygen	2	Carbon	75	
Wilder Works	Wilder, Ky.			Electric Arc	3	Carbon, alloy	85	
<u>International Harvester Co.</u>	Chicago, Ill.							Yes
South Chicago Works	S. Chicago, Ill.	1	3	Basic oxygen	2	Carbon, alloy	130	
Iowa Steel Mill, Inc.	Wilton, Iowa			Electric	1			
Wilton Works								
ITT Harper, Inc.	Morton Grove, Ill.			Electric Arc	2	Stainless	10 (1) 4 (1)	
Morton Grove Works				Electric induction	1	Stainless	1	

* Metric tons (1000 kg)

Table C-1(continued). IRON AND STEEL PRODUCING FACILITIES¹⁴

Company - Plant	Location	No. of agglomerating facilities	No. of blast furnaces	Type of furnace	Steel production		Size tons/heat	Coke production
					No. of furnaces	Steel grade		
Jesseop Steel Company Washington Works	Washington, Pa.			Electric Arc	4	Carbon, stainless alloy tool steel	16 (1) 14 (2) 8 (1)	
	Washington, Pa.			Electric Induction	1	Carbon & alloy tool steel	1/2	
				Electric Induction vacuum melt	1	Carbon & alloy tool steel	1	
				Electric Induction melt	2	Carbon & alloy tool steel	2 1/2	
				Ar - O ₂ vessel	1	Stainless	20	
				Electric Arc	2	Carbon, alloy stainless	60	
Green River Steel - Owensboro Works	Owensboro, Ky.							
Jones & Laughlin Steel Corp.	Pittsburgh, Pa.							
Allegheny Works Division	Allegheny, Pa.	1	5	Basic oxygen	3	Carbon, high strength, alloy	207	Yes
Pittsburgh Works Division	Pittsburgh, Pa.		4	Basic open hearth	6	Carbon, high strength & alloy	340	Yes
				Electric Arc	1	Carbon, alloy stainless	2	

* Metric tons (1000 kg)

Table C-1 (continued). IRON AND STEEL PRODUCING FACILITIES¹⁴

Company - Plant	Location	No. of agglomerating facilities	No. of blast furnaces	Type of furnace	Steel production		Size tonne/heat	Coke production
					No. of furnaces	Steel grade		
Cleveland Works Div.	Cleveland, Ohio	1	2	Basic oxygen	2	Carbon, high strength	220	
				Electric arc	2	Carbon, high strength	170	
				Electric arc	5	Alloy, stainless	60	
				A.O. vessel	1	Stainless	70	
				Electric arc	2	Carbon, alloy, stainless	40	
				Electric arc	3	Stainless	20 (1) 17 (2)	
				A.O.D. vessel	1	Stainless	17	
				Electric arc	1	Carbon	45	
				Basic open hearth	8	Carbon & alloy	225	Yes
		2	4					

* Metric tons (1000 kg)

Table C-1(continued). IRON AND STEEL PRODUCING FACILITIES¹⁴

Company - Plant	Location	No. of agglomerating facilities	No. of blast furnaces	Type of furnace	Steel production		Size range/heat	Coke production
					No. of furnaces	Steel grade		
Fontana Works					3	Carbon & alloy	120	
Kentucky Electric Steel Co.	Ashland, Ky.							
Coalton Works	Coalton, Ky.			Electric arc	3	Carbon	15	
Keystone Consolidated Ind., Inc.								
Peoria Works	Peoria, Ill.			Electric arc	2	Carbon	170	
Laclede Steel Co.	St. Louis, Mo.							
Alton Works	Alton, Ill.			Electric arc	2		225	
Lone Star Steel Company	Dallas, Texas							
Lone Star Works	Lone Star, Tex.		1	Basic open hearth	5	Carbon	250	Yes
Lukens Steel Company	Coatesville, Pa.							
Coatesville Works	Coatesville, Pa.			Basic open hearth	6	Carbon, alloy	145	
				Electric arc	4	Carbon, alloy	150 (2) 100 (2)	
Marathon Letourneau Co.	Longview, Tex.							
Longview Works	Longview, Tex.			Electric arc	2	Carbon, alloy	25	
Marathon Steel Company	Tempe, Ariz.							
Tempe Works	Tempe, Ariz.			Electric arc	3	Carbon, alloy	20	

* Metric tons (1000 kg)

Table C-1(continued). IRON AND STEEL PRODUCING FACILITIES¹⁴

Company - Plant	Location	No. of agglomerating facilities	No. of blast furnaces	Type of furnace	Steel production		Size tonne/heat	Coke production
					No. of furnaces	Steel grade		
<u>McLouth Steel Corporation</u>								
	Detroit, Mich.		2	Electric Arc	2	Carbon, stainless	200	
				Basic oxygen	5	Carbon, stainless	120	
<u>Nesta Machine Company</u>	Pittsburgh, Pa.							
<u>West Homestead Plant</u>	West Homestead, Pa.			Acid open hearth	4	Carbon, alloy	40 (1) 50 (1) 125 (2)	
<u>New Castle Plant</u>	New Castle, Pa.			Acid open hearth	4	Carbon, alloy	35 (1) 50 (2) 100 (1)	
<u>Mississippi Steel Div. of Nucor Corporation</u>	Jackson, Miss.			Electric Arc	3	Carbon	14 (2) 35 (1)	
<u>National Forge Company</u>	Irvine, Pa.							
<u>Irvine Works</u>	Irvine, Pa.			Electric Arc	2	Carbon, alloy, stainless	20 (1) 45 (1)	
<u>Erie Plant</u>	Erie, Pa.			Electric Arc	3	Carbon, alloy, stainless	35 (1) 75 (2)	
<u>National Steel Corp. Blast Furnace Div.</u>	Pittsburgh, Pa. River Rouge, Mich.	1	4					Yes

* Metric tons (1000 kg)

Table C-1(continued). IRON AND STEEL PRODUCING FACILITIES¹⁴

Company - Plant	Location	No. of agglomerating facilities	No. of blast furnaces	Type of furnace	Steel production		Size tonnes/heat	Coke production
					No. of furnaces	Steel grade		
Ecorse Works	Detroit, Mich.			Basic oxygen	4	Carbon, alloy	200 {2} 300 {2}	
Weirton Plant	Weirton, W. Va.	2	4	Electric Arc	2	Carbon, alloy	150	
Granite City Works	Granite City, Ill.	1	2	Basic oxygen	2	Carbon	335	Yes
New Jersey Steel & Structural Corporation	Sayreville, N.J.			Basic oxygen	2	Carbon	220	Yes
North Star Steel Company				Electric Arc	2	Carbon	65	
Ramsey County Works	Ramsey County, Minn.			Electric Arc	2	Carbon, alloy	60	
Northwest Steel Rolling Mills, Inc.								
Kent Works	Kent, Washington			Electric Arc	2	Carbon	35	
Northwestern Steel and Wire Company	Sterling, Ill.							
Sterling Works	Sterling, Ill.			Electric Arc	3	Carbon	150 {1} 250 {1} 400 {1}	
Oregon Steel Mills	Portland, Oregon							
Front Avenue Plant				Electric Arc	3	Carbon & low alloy	23	
Rivergate Plant				Electric Arc	2	Carbon & low alloy	75	
Pacific States Steel Corp.	Union City, Ca.			Basic open hearth	4	Carbon, alloy	150	

* Metric tons (1000 kg)

Table C-1(continued). IRON AND STEEL PRODUCING FACILITIES¹⁴

Company - Plant	Location	No. of agglomerating facilities	No. of blast furnaces	Type of furnace	Steel production		Size tons/heat	Coke production
					No. of furnaces	Steel grade		
<u>Phoenix Steel Corp.</u>	Claymont, Del.			Electric Arc	2	Carbon, alloy, stainless	150	
Plate Division	Claymont, Del.			Basic open hearth	4	Carbon, alloy	150	
Structural & Tube Div.	Phoenixville, Pa.							
<u>Porter Company, Inc., H.K.</u>	Pittsburgh, Pa.			Electric arc	2	Carbon	30	
Conners Steel Div. - Conners Works	Birmingham, Ala.			Electric arc	2	Carbon, alloy	30	
West Virginia Works	Huntington, W. Va.							
<u>Republic Steel Corp.</u>	Cleveland, Ohio		3					Yes
Youngstown Works	Youngstown, Ohio			Basic oxygen	2	Carbon, alloy	150	Yes
Warren Works	Warren & Milled, Ohio	1	1	Electric Arc	2	Carbon, alloy	185	
Massillon Works	Massillon, Ohio		1	Electric Arc	9	Carbon, alloy, stainless	80 (5) 200 (4)	Yes
Canton Works	Canton, Ohio			Vacuum melt electrode	8	Alloy, stainless & special steels	5 to 10	

* Metric Tons (1000 kg)

Table C-1(continued). IRON AND STEEL PRODUCING FACILITIES¹⁴

Company - Plant	Location	No. of agglomerating facilities	No. of blast furnaces	Type of furnace	Steel production		Size tonnes/heat	Coke production
					No. of furnaces	Steel grade		
Cleveland District	Cleveland, Ohio	1	5	Basic oxygen	2	Carbon, alloy	220	Yes
Buffalo Works	Buffalo, N.Y.		2	Basic open hearth	4	Carbon, alloy	400	
South Chicago Works	South Chicago, Ill.		1	Basic oxygen	2	Carbon, alloy	100	
				Basic open hearth	4	Carbon, alloy	250	Yes
				Electric Arc	3	Carbon, alloy	150	
Gulfsteel Works	Gadsden, Ala.	1	2	Basic oxygen	2	Carbon, alloy	150	Yes
				Electric Arc	2	Carbon, alloy	185	
Thomas Works								Yes
Finkl & Sons Co., A.	Chicago, Ill.			Electric Arc	2	Carbon, alloy	65	
Roblin Steel Company	N. Tonawanda, N.Y.							
Dunkirk Works	Dunkirk, N.Y.			Electric Arc	2	Carbon, alloy	25	
Sharon Steel Corp.	Sharon, Pa.							
Steel Division	Sharon, Pa.		2	Basic oxygen (L-D)	1	Carbon, alloy	150	
				Basic oxygen	2	Carbon, alloy	150	
				Electric Arc	2	Alloy, stainless	110	

* Metric Tons (1000 kg)

Table C-1 (continued). IRON AND STEEL PRODUCING FACILITIES¹⁴

Company - Plant	Location	No. of agglomerating facilities	No. of blast furnaces	Type of furnace	Steel production		Size tons#/heat	Coke production
					No. of furnaces	Steel grade		
Fairmont Coke Division	Fairmont, W. VA.							Yes
Coke Plant	Templeton, Pa.							Yes
Shenango Incorporated	Pittsburgh, Pa.							
Neville Plant	Neville Island, Pa.		2					Yes
Sharpville Plant	Sharpville, Pa.		1					Yes
Simonds Steel Division	Lockport, N.Y.							
Lockport Works	Lockport, N.Y.			Electric Arc	3	Carbon, alloy, stainless	15	
				Electric Induction Consumable electrode	2	Alloy	1 (1) 600 lbs (1)	
					3	Alloy	5	
Soule' Steel Company	San Francisco, Ca.							
Carson Works	Carson, Ca.			Electric Arc	2	Carbon	15	
Southwest Steel Rolling Mills	Los Angeles, Ca.							
Los Angeles Works	Los Angeles, Ca.			Electric Arc	2	Carbon	21 (1) 22 (1)	
Standard Steel	Burnham, Pa.							
Burnham Works	Burnham, Pa.			Basic electric arc	2	Carbon, alloy, stainless	40 (1) 18 (1)	
				Acid electric arc	2	Carbon, alloy	45 (1) 70 (1)	

* Metric Tons (1000 kg)

Table C-1(continued). IRON AND STEEL PRODUCING FACILITIES¹⁴

Company - Plant	Location	No. of agglomerating facilities	No. of blast furnaces	Type of furnace	Steel production		Size tons*/heat	Coke production
					No. of furnaces	Steel grade		
<u>Structural Metals, Inc.</u> Sequin Works <u>Teledyne Allvac</u> Monroe Works	Sequin, Texas Monroe, N.C. Monroe, N.C.			Vacuum electrode	2	Alloy, stainless, nonferrous alloy	11 (1) 23 (1)	
				Electric arc	2	Carbon	25	
				Vacuum induction	3	high strength high temp.	10.5 (1) 7.5 (1) 1.5 (1)	
				Vacuum melting electrode	5	high strength temp.	7.5	
				ESR melting electrode	5	high strength high temp	8	
<u>Teledyne Vasco</u> Vanadium Plant	Latrobe, Pa. Latrobe, Pa.			Electric induction	2	Carbon, alloy high speed	1/20 (1) 1/8 (1)	
				Electric induction	2	Carbon, alloy high speed	1/2 (1) 1 (1)	
				Electric arc	1	Carbon, alloy high speed	13	
				Vacuum melting electrode	2	Carbon alloy high speed	6.5	

* Metric Tons (1000 kg)

Table C-1(continued). IRON AND STEEL PRODUCING FACILITIES¹⁴

Company - Plant	Location	No. of agglomerating facilities	No. of blast furnaces	Type of furnace	Steel production		Size tonne/heat	Coke production
					No. of furnaces	Steel grade		
Colonia Plant Tennessee Forging Steel Corp. Harriman Works Kankakee Electric Steel Works Texas Steel Company	Monaca, Pa.			Vacuum melting electrode	1	Carbon, alloy high speed	1/10	
	Harriman, Tenn.			Electric arc	1	Carbon, alloy high speed	15	
	Harriman, Tenn.			Electric arc	2	Carbon, alloy	25	
	Kankakee, Ill.			Electric arc	2	Carbon, alloy	22	
	Ft. Worth, Tex.			Electric arc	3	Carbon, alloy & stainless	8 (1) 12 (1) 3 (1)	
Tlanken Company (The) Canton Works	Canton, Ohio			Electric arc	2	Carbon	25 (1) 30 (1)	
	Canton, Ohio			Electric Arc	7	Carbon, alloy, stainless	140 (2) 110 (4) 60 (1)	
				Vacuum melting electrode	1	Carbon, alloy, stainless	19	
Union Electric Steel Corp. Carnegie & Harmon Creek Plants	Pittsburgh, Pa. Carnegie & Harmon Creek, Pa.			Electric arc	1	Alloy	35	

* Metric Tons (1000 kg)

Table C-1(continued). IRON AND STEEL PRODUCING FACILITIES¹⁴

Company - Plant	Location	No. of agglomerating facilities	No. of blast furnaces	Type of furnace	Steel production		Size tons*/heat	Coke production
					No. of furnaces	Steel grade		
United States Pipe & Foundry Co.	Birmingham, Ala.							
Coke Plant	N. Birmingham, Ala.		1					Yes
Blast furnace	N. Birmingham, Ala.							
United States Steel Corp.	Pittsburgh, Pa.							
Clairton Works	Clairton, Pa.		1					Yes
Edgar Thomson-Irvin Works	Braddock, Pa.	1	5	Basic oxygen	2	Carbon, alloy	220	
Fairless Works	Fairless Hills, Pa.	2	3	Basic open hearth	9	Carbon, alloy	395	Yes
Homestead Works Blast Furnace	Rankin, Pa.	1	4					
Homestead Works - Steel Division	Homestead, Pa.			Basic open hearth	11	Carbon, alloy	320	
Johnstown - Canton Works	Johnstown, Pa.			Electric arc	3	Carbon, alloy, stainless	30 (1) 3 (2)	
Lorain - Cuyahoga Works	Lorain, Ohio	1	5	Basic oxygen	2	Carbon, alloy	225	Yes
Lorain - Cuyahoga Works - Central Fees	Cleveland, Ohio		2					

* Metric Tons (1000 kg)

Table C-1(continued). IRON AND STEEL PRODUCING FACILITIES¹⁴

Company - Plant	Location	No. of agglomerating facilities	No. of blast furnaces	Type of furnace	Steel production		Size tonne/heat	Coke production
					No. of furnaces	Steel grade		
National - Duquesne Works McKeesport	Duquesne, Pa.	1	3	Basic oxygen	2	Carbon, alloy	215	
National - Duquesne Works Duquesne			4	Electric arc	5	Alloy, stainless	20 (1) 50 (1) 85 (3)	
Youngstown Works		1	4	Basic open hearth	14	Carbon, alloy	163	
Duluth Works								Yes
Gary Works	Gary, Ind.	5	13	Basic open hearth	2	*		Yes
				Basic oxygen	6	Carbon, alloy	215 (3) 200 (3)	
South Works	S. Chicago, Ill.	1	8	Basic oxygen	3	Carbon, alloy	200	
				A.O.D. 4 strand billet caster	1	Stainless	90	
				Electric arc	1	Carbon	200	
Geneva Works	Geneva, Utah	2	3	Basic open hearth	10	Stainless	100	Yes
Torrance Plant	Torrance, Ca.			Basic open hearth	4	Carbon, alloy	340	
Fairfield District Works	Ale.	4	6	Basic open hearth	9	Carbon, alloy	63 340 (4) 230 (4) 150 (5)	Yes

* Metric Tons (1000 kg)

Table C-1(continued). IRON AND STEEL PRODUCING FACILITIES¹⁴

Company - Plant	Location	No. of agglomerating facilities	No. of blast furnaces	Type of furnace	Steel production		Size tona#/heat	Coke production
					No. of furnaces	Steel grade		
Texas Works	Baytown, Texas			Basic oxygen	2	Carbon, alloy	200	
Washington Steel Corp.	Washington, Pa.			Electric arc	2	Carbon, alloy	200	
Fitch Works	Houston, Pa.							
Wheeling-Pittsburgh Steel Corp.	Pittsburgh, Pa.			Electric arc	2	Stainless	35	
Steuenville Plant	Steuenville, Ohio	1	5	Basic oxygen	2	Carbon	275	Yes
Monessen Works	Monessen, Pa.	1	2	Basic oxygen	2	Carbon, alloy	200	Yes
Mittman Steel Mills	Fontana, Ca.			Electric	1	Carbon	25	
Youngstown Sheet & Tube Company	Youngstown, Ohio							
Campbell Works	Campbell, Ohio	1	4	Basic open hearth	12	Carbon & alloy	210	Yes
Brier Hill Works	Youngstown, Ohio		2	Basic open hearth	11	Carbon & alloy	175	Yes
Indiana Harbor Works	E. Chicago, Ind.	1	4	Basic open hearth	8	Carbon & alloy	315	Yes
				Basic oxygen	2	Carbon & alloy	290	

* Metric Tons (1000 kg)

Table C-2. DIRECT REDUCTION PLANTS IN OPERATION AND ON ORDER AS OF DECEMBER 1974¹⁵

Plant - location	Process	Start-up year	Annual rated capacity, tons product per year	
			A	B
Armco Steel, Houston, Texas	Armco	1973	330,000	
Korf Steel, Georgetown, South Carolina	Midrex	1971	350,000	
Gilmore Steel, Portland, Oregon	Midrex	1969	300,000	
HECLA, Casa Grande, Arizona ^c	SL/RN	1975		65,000

A = In operation.

B = On order.

c Process residues from calcines leaching-washing plant into sponge iron for use as precipitant for cement copper production.

Table C-3. U.S. IRON ORE PRODUCERS, SALIENT DATA¹⁶

Name of operation/ Location	Ownership managing partner under- lined	Haul- age (ore)	Ore mined (t/tpd)*	Ore grade %	Ore minerals	Conc. output grade (t/tpd)* %	Conc. (pellet methods plants)	Agglo mer- tion	Pellet firing (t/tpd)*	'74 pro- jected (t/tpd)*	% grade final product	Total em- ploy- ees
Arcturus mine Marble, Minn.	U.S. Steel	truck,	na	na	hem	-	h-m	-	-	na	na	na
Black River Falls mine Black River Falls, Wisc.	Inland steel	truck	9,000	33	mag	3,000 67	-	mag.sep.	pz sg	3,000 940,000	64.75	239
Butler Taconite Nashua, Minn.	Inland steel Hanna Mining Wheeling Steel	truck	22,800	21.8	mag	7,100 68	-	mag.sep.	pz g-k	8,000 2,626,000	66.1	520
Canisteo mine Coleraine, Minn.	Mesaba-Cliffs National Steel Cleveland Cliffs	truck	29,450	38.10	goe hem	8,100 56	wash, h-m	-	-	1,200,000	56	228
Cedar City mine Cedar City, Utah	Utah International	truck	6,000st	39.8	mag, hem	4,000st 58	h-m, mag. sep	-	-	na	na	na
Comstock mine Cedar City, Utah	CF&I Steel	truck conv	4,700nt	51.92	hem mag	-	-	-	-	950,000	51.92	na
Coons Pacific ¹ Eveleth, Minn.	Coons Pacific	-	-	-	hem	9,500 56-62	wash, jig, h-m, spir	-	-	na	-	57
Eagle Mountain mine Eagle Mountain, Calif.	Kaiser Steel	truck	30,000	34	hem mag	18,000 60	-	wash, jig, h-m, mag.sep.	pz sg	6,500 3,791,000	61	1,500
Empire Iron Mining Co. Ishteping, Mich.	Inland Steel McLouth Steel Cleveland Cliffs International Harvester	truck	45,000	33	mag	16,920 66.5	-	mag.sep flot siphon	pz g-k	10,085 4,060,000	64.65	827
Erle Mining Co. Hoyt Lakes, Minn.	Bethlehem Steel Youngstown S&T Steel Co. of Canada Interlake Pickands Mather	truck, rail	90,000	32	mag	29,600 62.5	-	mag.sep	pz vst	29,100 10,600,000	62.5	2,768

* To convert to metric tons per day multiply by 1.016

Table C-3(continued). U.S. IRON ORE PRODUCERS, SALIENT DATA¹⁶

Name of operation/ location	Ownership managing partner under- lined	haul- age (ore)	Ore mined (1tpd)*	Ore grade %	Ore minerals	Conc. out- put (1tpd)*	Conc. grade %	Conc. methods (plants)	Agglo- meration firing	'74 pro- jected (1tpd)*	% grade final product	Total em- ploy- ees	
Eveleth Expansion Co. Eveleth, Minn.	Arco Steel Steel Co. of Canada <u>Oglebay Norton</u> Dofasco	truck	na	na	na	na	na	mag.sep	pz g-k	na	na	na	
Eveleth Taconite Co. Eveleth, Minn.	<u>Ford Motor</u> <u>Oglebay Norton</u>	truck, rail	17,000	23.5	mag	5,567	67.12	mag.sep	pz g-k	5,700	2,300,000	64.4	472
Grace Mine Morgantown, Pa.	Bethlehem Steel	1-h-d, conv	7,025	41.75	mag, chalc	4,900	66.35	mag.sep	pz vst	4,900	1,160,700	65.4	815
Gross-Melton mine Eveleth, Minn.	Rhude & Fryberger	truck	6,000	48	hem	3,600	54	wash, jig, h-m	-	-	300,000	54	55
Groveland mine Bendville, Mich.	Hanna Mining	truck	14,250	35	hem, mag	5,850	61	mag.sep, flat	pz sg	6,000	2,045,000	63	475
Hill Anax mine Calumet, Minn.	Jones & Laughlin	truck, conv	20,000	36.55	geo, hem, lim	6,000	59.67	wash, h-m, h-m, cyc, spir	-	-	940,000	58	200
Hill Rust mine Hibbing, Minn.	Rhude & Fryberger	truck	4,000	58	hem	3,200	54	wash	-	-	150,000	54	49
Jackson County Iron Co., Black River Falls, Wis.	Inland Steel	truck	7,500	36	mag	2,700	67.75	mag.sep	pz sg	na	920,000	64.91	242
Lind-Greenway mine Grand Rapids, Minn.	Jones & Laughlin	truck	20,000	30	geo, hem, lim	5,800	58.70	wash, jig, h-m	-	-	910,000	58.70	170
Lone Star Steel Co. Lone Star, Texas	Northwest Industries	truck	na	26.68	lim, sid	3,821	42.10	wash	- sm rotary kilns	-	na	52.60	132

* To convert to metric tons per day multiply by 1.016

Table C-3(continued). U.S. IRON ORE PRODUCERS, SALIENT DATA¹⁶

Name of operation/ location	Ownership managing partner under- lined	Haul- age (ore)	Ore mined (t/yr)*	Ore grade %	Ore minerals	Conc. output grade (t/yr)*	Conc. % grade	Conc. methods (plants)	Agglo mer- tion	Pellet firing (t/yr)*	'74 pro- jected (t/yr)*	% grade final product	Total em- ploy- ees
Luck Mining Co. Silver City, N.M.	Private	truck	180	43	hem	none	-	-	-	-	40,000	43	11
MacIntyre Development Tahoe, N.Y.	M L Industries	truck	5,000	28	mag	1,000	62.64	mag. sep	-	-	261,000(gt)	62.64	186
Mathew mine Isipeming, Mich.	Republic Steel Bethlehem Steel McLouth Steel Cleveland Cliffs Sharon Steel	rail, hoist	7,300	54.69	hem, mar	-	-	-	-	-	1,954,000	60.22	575
McKinley mine McKinley, Minn.	Jones & Laughlin	truck	17,000	56.5	goe, hem, lim	12,000	60	wash	-	-	2,240,000	60	245
Meramec Mining Co. Sullivan, Mo.	Bethlehem Steel St. Joe Minerals	truck, rail, conv	8,500	45	mag	5,500	69	mag, sep flot, fine scr	pz	vst	4,800	67	na
Minnetac Plant Mt. Iron, Minn.	U S Steel	truck, rail	110,000	22	mag	35,000	65	mag, sep	pz	g-k	35,000	65.3	2,940
National Steel Pellet Plant Keweenaw, Minn.	National Steel Hanna Mining	truck, conv	24,000	31	mag	7,200	67.2	mag, sep	pz	g-k	7,740	65.7	569
Nevada Barth Corp. Carlin, Nev.	Nevada-Barth	truck	1,200	60	hem, mag	none	none	-	-	-	105,000	60	20
Pilot Knob Pellet Co. Ironton, Mo.	Hanna Mining Granite City Steel	conv, h-d	5,979	34.6	mag	5,616	65	mag, sep flot	pz	sg	4,080	63.46	435
Pioneer Pellet Plant Isipeming, Mich.	Republic Steel Bethlehem Steel McLouth Steel Cleveland Cliffs Sharon Steel	-	-	-	hem, mar	4,800	60.75	h-m	pz	g-k	4,616	61.5	113

* To convert to metric tons per day multiply by 1.016

Table C-3(continued). U.S. IRON ORE PRODUCERS, SALIENT DATA¹⁶

Name of operation/ location	Ownership managing partner under- lined	Haul- age (ore)	Ore mined (t/tpd)*	Ore grade %	Ore minerals	Conc. output grade (t/tpd)* %	Conc. wash, h-m	Conc. methods (plants)	Agglo- meration flotation	Pellet firing (t/tpd)*	'74 pro- jected (t/tpd)*	% grade final product	Total em- ploy- ees
Plummer mine Coleraine, Minn.	U.S. Steel	truck, conv	na	na	hem	na	na	na	-	-	na	59.9	na
Republic mine Isipeming, Mi.	Jones & Laughlin Cleveland Cliffs Wheeling Pitts- International Harvester	truck	24,200	36	hem mag	10,400 65.37	-	flot, elut	pz	g-k	na	65.2	831
Menville mine Chisholm, Minn.	Pittsburgh Pacific	truck	8,650	na	hem	na	na	na	-	-	200,000	na	226**
New York Division Star Lake, N.Y.	Jones & Laughlin 2	truck	9,600	23.2	mag, mar	2,730 66.3	-	mag, sep spir	sn	-	943,000	65.2	509
Rana mine Kinney, Minn.	Rhude & Freyberger	truck	3,600	58	hem	2,400 52	wash	-	-	-	100,000	52	29
Reserve Mining Co. Silver Bay, Minn.	Republic Steel Armco Steel	truck	85,000	24	mag	28,500 64.6	-	mag, sep	pz	sg	29,500	60.76	2,850
Rouchieu group Virginia, Minn.	U.S. Steel	truck, rail	na	na	hem, lim	na	na	crush, scr, h-m	-	-	na	58.17	na
Sherman mine Chisholm, Minn.	U.S. Steel	truck, rail	na	na	hem, lim	na	na	wet scr, h-m	-	-	na	59.18	na
Sherwood mine Iron River, Mich.	Inland Steel	rail, conv, hoist	1,600	54.7	goe, hem	na	na	-	-	-	385,000	55	109
Stephens mine Aurora, Mich.	U.S. Steel	truck	na	na	na	na	na	crush, scr	-	-	na	58.10	na

*To convert to metric tons per day multiply by 1.016

Table C-3(continued). U.S. IRON ORE PRODUCERS, SALIENT DATA¹⁶

Name of operation/ location	Ownership managing partner under- lined	Haul- age (ore)	Ore mined (1tpd)*	Ore grade %	Ore minerals	Conc. output, grade (1tpd)* %	Conc. methods (plants)	Agglo Pellets firing (1tpd)*	'74 pro- jected (1tpd)*	% grade final product	Total em- ploy- ees
Sunrise mine Sunrise, Wyo.	CF&I Steel	rail, conv, hoist	na	na	hem	2,400nt 48.99	jig, h-m	-	500,000	48.99	225
Tilden Mining Co. Isbopeming, Mich.	Algoma Steel Jones & Laughlin Cleveland Cliffs Steeco Coal Wheeling Pitts. Sharon Steel	truck	36,800	36	hem	12,300 65.61	-	pz g-k 11,000 flot, selec- tive floc	none	65.90	618
U S Pipe & Foundry Co. Russellville, Ala.	Jim Walter Corp.	truck	700	48	goe	1,000 50+	h-m, flot	-	na	na	82
Whitney mine Hibbing, Minn.	National Steel Hanna Mining	truck, conv	20,300	na	goe, hem	13,500 52.6	wash, h-m	-	700,000	52.6	337
Wyoming mine Virginia, Minn.	Pittsburgh Pacific*	truck	3,200	na	hem	na	h-m	-	175,000 (conc)	na	226**

na - not available
hem - hematite
h-m - heavy media
mag - magnetic
mag sep - magnetic separation
pz - pelletizing
sg - straight gate
g-k - grate-kill
goe - goethite
wash - washing
st - short tons

conv - conveyor
nt - net tons
jig - jigging
spir - spirals
flot - flotation
l-h-d - load haul dump
siphon - siphonizers
vsf - vertical shaft furnace
chalc - chalcocite
lim - limestone
cyc - cyclones

sid - siderite
gt - gross tons
fine scr - fine screening
mar - martite
clut - elutriation
** - combined total for Neville, Wyoming mines
sn - sintering
scr - screening
wet scr - wet screening
floc - flocculation
* - leased for U.S. Steel

* To convert to metric tons per day multiply by 1.016

Table C-4. MINE AND PLANT EXPANSIONS - IRON AND STEEL INDUSTRY IN USA - 1975¹⁷

Company	Location	Project ^a	Capacity planned tpy*	Start	Notes
Bethlehem Steel	Cornwall, Pa.	co/pp	762M	1975	Reopening of plant closed down in mid-1973.
Cleveland Cliffs Iron	Tilden, Mi.	mi/co/pp	10.2MM	1974	Recoverable reserves over 900MM tons of 36% iron ore. Started up in fourth quarter 1974.
Cleveland Cliffs	Empire, Mi.	mi/co/pp	5.4MM	1974	Possible further expansion.
Eveleth Taconite	Eveleth, Mn.	co/pp	6.1MM	1976	Partners in the expansion are Stelco, Dofasco, Armco Steel.
Hibbing Taconite	Hibbing, Mn.	pp	5.5MM	1976	Jointly owned by Bethlehem Steel and Pickands Mather.
Inland Steel	Minorca, Mn.	co/pp	2.6MM	1978	The co plant to be built by Bechtel and pp by Dravo.
Mitsubishi U.S. Steel	Klukwan, Al.	mi/pp	3.6MM		Capacity reduced from original 5MM tpy of pellets. Deliveries would start 3-1/2 yr after construction starts.
National Steel Plant	Keewatin, Mn.	pp	6.1MM	1977	NSP is owned by National Steel 85% and Hanna Mining 15%.
U.S. Steel	Virginia, Mn.	co/pp		1978	
Sovereign, In. Krupp	Black Mt., Az.	mi/pp	18.3MM		Tentative agreement for partnership.

^a Abbreviations: co - concentrator, pp - pellet plant, mi - mine, M - thousands, MM - millions.

* Metric Tons (1000 kg)

Table C-5. MAJOR CAPTIVE STEEL COAL MINES¹⁸

Controlling company	Operating company	State	Production, metric tons, 1974
1. U.S. Steel Corp.	U.S. Steel Corp.	Ala., W. Va., Ky., Colo., Pa., Utah	14,865,306
2. Bethlehem Steel Co.	Bethlehem Mines Corp. Beth-Elkhorn Coal Corp.	Pa., W. Va., Ky.	8,995,124 3,111,566
3. Republic Steel Corp.	Republic Steel Corp.	Pa., Ky.	2,676,797
4. Jones & Laughlin Steel Corp.	Jones & Laughlin Steel Corp. Gateway Coal Co.	Pa. Pa.	1,639,469 990,758
5. Youngstown Sheet & Tube Co.	Olga Coal Co. Buckeye Coal Co. Youngstown Mines Corp.	W. Va. Pa. W. Va.	1,148,662 796,553 419,229
6. Inland Steel Co.	Inland Steel Co.	Ill.	2,239,849
7. Kaiser Steel Corp.	Kaiser Steel Corp.	N. M., Utah	1,859,365
8. Armco Steel Corp.	Armco Steel Corp. Big Mountain Coal, Inc.	W. Va. W. Va.	1,355,737 414,949
9. Cannelton Industries, Inc.	Cannelton Coal Co. (Div. of Algoma Steel Corp.) Maple Meadows Mining Co.	W. Va. W. Va.	1,761,217 9,504*
10. National Steel Corp.	National Mines Corp.	Pa., Ky.	1,754,256
11. Steel Co. of Canada	Pikeville Coal Co.	Ky. E	720,323
12. CF & I Steel Corp.	CF & I Steel Corp.	Colo.	489,655

Table C-5(Continued). MAJOR CAPTIVE STEEL COAL MINES¹⁸

Controlling company	Operating company	State	Production, metric tons, 1974
13. Wheeling-Pittsburgh Steel Corp.	W-P Steel Corp.	W. Va.	397,350
14. Keller Steel Co.	Buckeye Coal Mining Co. Industrial Mining Co.	Ohio Ohio	93,379 88,054
Total			45,827,102

* 4989 TPD capacity.

Table C-6(continued). COKE-OVEN PLANTS IN THE UNITED STATES ON DECEMBER 31, 1973^{1,19}

Name and address of company	Location of plant	Classification of plant	Major uses of coke		Coal-chemical materials produced ³
			Captive ²	Commercial sales	
Illinois, continued Republic Steel Corp. P.O. Box 6778 Cleveland, Ohio 44101	Chicago	Furnace	BF, other industrial		1,5,6,13,19A
Indiana Bethlehem Steel Corp. Bethlehem, Pennsylvania 18016	Burns Harbor	Furnace	BF,		1,5
Citizens Gas & Coke Utility 2020 North Meridian Street Indianapolis, Indiana 46202	Indianapolis	Merchant	Other industrial	BF, foundry, other industrial	5
Indiana Gas & Chemical Corp. 13th & Hulman Streets Terre Haute, Indiana 47802	Terre Haute	Merchant		Foundry, other industrial	5,13,14,15,16,17
Inland Steel Co. 30 West Monroe Street Chicago, Illinois 60603	Indiana Harbor	Furnace	BF		1,5,7,13
U.S. Steel Corp. 600 Grant Street Pittsburgh, Pennsylvania 15230	Gary	Furnace	BF, other industrial		1,5,6,12,13,19A
Youngstown Sheet & Tube Co. P.O. Box 900 Youngstown, Ohio 44501	Indiana Harbor	Furnace	BF, other industrial		2,5,13,18
Kentucky Allied Chemical Corp. P.O. Box 1013R Morristown, New Jersey 07960	Ashland	Merchant		BF	2,5,7,13
Maryland Bethlehem Steel Corp. Bethlehem, Pennsylvania 18016	Sparrows Point	Furnace	BF, other industrial		1,5,13,14,15,16,18
Michigan Allied Chemical Corp. P.O. Box 1013R Morristown, New Jersey 07960	Detroit	Merchant	Foundry, other industrial	BF, foundry, other industrial	5
Ford Motor Co. The American Road Dearborn, Michigan 48121	Rouge	Furnace	BF, foundry, other industrial	Other industrial	3,5,13

Table C-6(continued). COKE-OVEN PLANTS IN THE UNITED STATES ON DECEMBER 31, 1973^{1,19}

Name and address of company	Location of plant	Classification of plant	Major uses of coke		Coal-chemical materials produced ³
			Captive ²	Commercial sales	
Michigan, continued					
Great Lakes Steel Corp., Detroit, Michigan 48229	Zug Island	Furnace	BF	BF	1,5,8,13
Minnesota					
Koppers Co., Inc., 1000 North Hamline Avenue St. Paul, Minnesota 55104	St. Paul	Merchant		Foundry, other Industrial	5
U.S. Steel Corp., 600 Grant Street Pittsburgh, Pennsylvania 15230	Duluth	Furnace	BF, other Industrial	Other Industrial	1,5
Missouri					
Great Lakes Carbon Corp., 299 Park Avenue New York, New York 10017	St. Louis	Merchant	Foundry, other Industrial	Foundry, other Industrial	5
New York					
Allied Chemical Corp., P.O. Box 1013R Morrisstown, New Jersey 07960	Buffalo	Merchant	Foundry, other Industrial	BF, foundry, other Industrial	2,5,7,13
Bethlehem Steel Corp., Bethlehem, Pennsylvania 18016	Lackawanna	Furnace	BF		1,5,8,13,18
Donner-Hanna Coke Corp., Abby & Mystic Streets Buffalo, New York 14220	Buffalo	Furnace	BF, other Industrial	Other Industrial	1,5,8,13
Ohio					
Allied Chemical Corp., P.O. Box 1013R Morrisstown, New Jersey 07960	Ironton	Merchant	Foundry, other Industrial	BF, foundry, other Industrial	2,5,7,13
Armco Steel Corp., Middletown, Ohio 45042	Hamilton	Furnace	BF	Foundry, other Industrial	1,5,13
Armco Steel Corp., Middletown, Ohio 45042	Middletown	Furnace	BF	Other Industrial	1,5,8,13,14,14A, 15,16,17,18
Diamond Shamrock Chemical Co., 1100 Superior Avenue Cleveland, Ohio 44115	Painesville	Merchant	Other industrial	Foundry, other Industrial	2,5
Empire-Detroit Steel Division Portsmouth, Ohio 45662	Portsmouth	Furnace	BF, other Industrial		5,13

Table C-6(continued). COKE-OVEN PLANTS IN THE UNITED STATES ON DECEMBER 31, 1973^{1,19}

Name and address of company	Location of plant	Classification of plant	Major uses of coke		Coal-chemical materials produced ³
			Captive ²	Commercial sales	
Ohio, continued					
Interlake Steel Corp. 135th Street & Perry Avenue Riverdale, Illinois 60627	Toledo	Furnace	BF	BF	1,5,13,14,15,16
Republic Steel Corp. P.O. Box 6778 Cleveland, Ohio 44101	Cleveland	Furnace	BF		1,5,8,13,14,15, 16,17,19
Republic Steel Corp. P.O. Box 6778 Cleveland, Ohio 44101	Massillon	Furnace	BF, other industrial	BF	1,5,13
Republic Steel Corp. P.O. Box 6778 Cleveland, Ohio 44101	Warren	Furnace	BF		1,5,13,19
Republic Steel Corp. P.O. Box 6778 Cleveland, Ohio 44101	Youngstown	Furnace	BF, other industrial		1,5,13,14,15, 16,17,19
Youngstown Sheet & Tube Co. P.O. Box 900 Youngstown, Ohio 44501	Campbell	Furnace	BF		1,5,13
U.S. Steel Corp. 600 Grant Street Pittsburgh, Pennsylvania 15230	Lorain	Furnace	BF	BF	1,5,13
Pennsylvania Alan Wood Steel Co. Consolocken, Pennsylvania 19428	Swedeland	Furnace	BF, other industrial	BF, foundry, other industrial	5,13,14A,17
Bethlehem Steel Corp. Bethlehem, Pennsylvania 18016	Bethlehem	Furnace	BF, other industrial		1,5,13,14,15, 16,18,19
Bethlehem Steel Corp. Bethlehem, Pennsylvania 18016	Johnstown	Furnace	BF, other industrial		1,5,7,12,13,17, 18
Crucible Steel Corp. P.O. Box 226 Midland, Pennsylvania 15059	Midland	Furnace	BF, other industrial	BF	1,5,8,13
Eastern Gas & Fuel Associates 4501 Richmond Street Philadelphia, Pennsylvania 19137	Philadelphia	Merchant		Foundry, other industrial	5

Table C-6(continued). COKE-OVEN PLANTS IN THE UNITED STATES ON DECEMBER 31, 1973^{1,19}

Name and address of company	Location of plant	Classification of plant	Major uses of coke		Coal-chemical materials produced ³
			Captive ²	Commercial sales	
Koppers Co., Inc. P.O. Box 739 Erie, Pennsylvania 16512	Erie	Merchant			5
Jones & Laughlin Steel Corp. Alliquippa, Pennsylvania 15001	Alliquippa	Furnace	BF, other industrial	BF, foundry, other industrial	1.5, 8, 13, 14, 14A, 15, 16, 17
Jones & Laughlin Steel Corp. 2709 East Carson Street Pittsburgh, Pennsylvania 15203	Pittsburgh	Furnace	BF, other industrial		1.5, 8, 13
Wheeling-Pittsburgh Steel Corp. 1134-40 Market Street Wheeling, West Virginia 26003	Monessen	Furnace	BF	Other industrial	1.5, 8, 13
Shenango Inc. Neville Island Pittsburgh, Pennsylvania 15225	Neville Island	Furnace	BF, foundry	BF, foundry	1.5, 8, 13
U.S. Steel Corp. 600 Grant Street Pittsburgh, Pennsylvania 15230	Clairton	Furnace	BF	Other industrial	5, 6, 6A, 9, 9A, 10, 11, 12, 12B, 13, 14, 15, 16, 17, 19, 19A, 21, 22
U.S. Steel Corp. 600 Grant Street Pittsburgh, Pennsylvania 15230	Fairless	Furnace	BF		1.5, 8, 15, 19
Chattanooga Coke & Chemical Co., Inc. 4800 Central Avenue Chattanooga, Tennessee 37410	Alton Park	Furnace	Foundry	Foundry, other industrial	1.5, 13, 14, 15, 16
Arco Steel Corp. P.O. Box 1367 Houston, Texas 77001	Houston	Furnace	BF		5
Lone Star Steel Co. P.O. Box 35888 Dallas, Texas 75235	Dalingerfield	Furnace	BF, foundry		1.5, 13, 14, 15, 16, 17
U.S. Steel Corp. 600 Grant Street Pittsburgh, Pennsylvania 15230	Geneva	Furnace	BF, other industrial	Other industrial	1.5, 13, 14, 15, 16, 17, 19

Table C-6(continued). COKE-OVEN PLANTS IN THE UNITED STATES ON DECEMBER 31, 1973^{1,19}

Name and address of company	Location of plant	Classification of plant	Major uses of coke		Coal-chemical materials produced ³
			Captive ²	Commercial sales	
West Virginia National Steel Corp. Weirton, West Virginia 26062	Weirton	Furnace	BF, other industrial	Other industrial	1,5,7,8,13,18
Sharon Steel Corp. P.O. Box 291 Sharon, Pennsylvania 16146	Fairmont	Furnace	BF	Other industrial	1,5,13
Wheeling-Pittsburgh Steel Corp. 1134-40 Market Street Wheeling, West Virginia 26003	East Steubenville	Furnace	BF	Other industrial	1,5,7,8,12,13
Wisconsin Milwaukee Solvay Coke Division Pickands Mather 311 East Greenfield Avenue Milwaukee, Wisconsin 53204	Milwaukee	Merchant		BF, foundry, other industrial	5

¹ Residential and commercial heating included in other industrial.

² Coke transferred to integrated operations and to affiliated companies.

³ Numbers in this column refer to coal-chemical materials produced at coke plants as follows:

- 1 - Ammonium sulfate.
- 2 - Ammonia liquor (NH₃ content).
- 3 - Diammonium phosphate.
- 4 - Monoammonium phosphate.
- 5 - Crude coal tar.
- 6 - Cresosote oil, straight distillate.
- 6A - Cresosote oil, in coal-tar solution.
- 7 - Crude chemical oil (tar acid oil).
- 8 - Sodium phenolate or carbolate.
- 9 - Phenol (industrial grades).
- 9A - Phenol, all other grades.
- 10 - Cresols.
- 11 - Cresylic acid.
- 12 - Pitch-of-tar, soft, (s.p. minus 110°).
- 12A - Pitch-of-tar, medium (s.p. 110° to 160°F).
- 12B - Pitch-of-tar, hard (s.p. over 160°F).
- 13 - Crude light oil.
- 14 - Benzene, specification grades.
- 14A - Benzene, other industrial grades.
- 15 - Toluene, all grades.
- 16 - Xylene, all grades.
- 17 - Solvent naphtha, all grades.
- 18 - Intermediate light oil.
- 19 - Naphthalene, crude, solidifying under 74°C.
- 19A - Naphthalene, crude, solidifying from 74° to 79°C.
- 20 - Pyridine, crude bases.
- 20A - Pyridine, refined (2°C).
- 21 - Picolines.
- 22 - Sulfur.

Table C-7. SUMMARY OF COKE-OVEN OPERATIONS IN THE UNITED STATES IN 1974,
BY STATES⁸

State	Plants in existence Dec. 31	Coal carbonized (thousand tons)*	Yield of coke from coal (percent)	Coke produced (thousand tons)*
Alabama	7	6,635	70.49	4,647
California, Colorado, Utah	3	4,817	62.89	3,012
Maryland and New York	4	8,448	68.61	5,858
Illinois	4	2,733	62.45	1,735
Indiana	6	12,467	66.48	8,231
Kentucky, Missouri, Tennessee, Texas	5	2,537	67.74	1,742
Michigan	3	4,110	73.08	2,957
Minnesota and Wisconsin	3	1,181	70.69	866
Ohio	12	11,764	68.64	8,022
Pennsylvania	13	21,141	69.31	14,808
West Virginia	3	4,774	69.93	3,225
Total in 1974	63	80,607	68.42	55,103

* Metric Tons (1000 kg)

APPENDIX D

ENERGY AND UTILITY REQUIREMENTS

Table D-1. ENERGY CONSUMPTION IN THE STEEL INDUSTRY - 1972^{a,20}

Major source	Actual consumption	Percent
Coal, tons ^b	60.78×10^6	63
Natural gas, liters	10.5×10^{12}	21.7
Fuel oil, liters	5.42×10^6	6.7
LP gas, liters	3.47×10^8	0.1
Electricity, kWh	4.72×10^{10}	5.2
Others		3.3

^aTotal steel production was 120.88 million metric tons.

^bIn addition to the coal quantities listed, an additional 11 million metric tons of coal were used by coke ovens and boilers with equivalent Btu's transferred to other than steel consumers in the form of electricity, steam and coke oven products.

Table D-2. WATER REQUIREMENTS OF THE IRON AND
STEEL INDUSTRY - 1964^{a,21}

Process/Mill	Process water, liters per ton* of steel	Cooling water, liters per ton of steel
Blast furnace	9,100	19,000
Open hearth furnace	33	16,100
Basic oxygen furnace	262	1,200
Electric furnaces	33	2,100
Hot-rolling mills and related	15,400	15,400
Cold mills and related	8,700	-
Coke plants	200	20,800
Sanitary, boilers, etc.		8,300
Blowers, condensers, etc.		64,200

^a Total production of steel was 115.3 million tons. Estimated process water and cooling water reuse were 18.1 and 52.2 percent, respectively.

* Metric Tons (1000 kg)

APPENDIX E

EMISSION DATA

Table E-1. QUANTITIES OF POLLUTANTS DISCHARGED FROM IRON AND STEEL INDUSTRY⁵
BEFORE TREATMENT IN 1971^{23,24,25,26}
(Thousand metric tons)

Pollutants	Sintering	Materials handling	Reduction, blast furnace	STEEL FURNACE			Scarfig	Pickling	Rolling mill	Coking, by-product
				Open hearth	Basic oxygen	Electric arc				
<u>Air Pollutants</u>										
Particulates	882	545	4810	296	1580	166	163			59.2
Ammonia	-	-	-	-	-	-	-			203
<u>Water Pollutants</u>										
Suspended solids	470	-	2464	3780 ^a	-	-	-		4578	-
Ammonia										2.84
Cyanide										0.41
Phenol										2.19
FeSO ₄								458		
H ₂ SO ₄								123		

^a Total for open hearth and basic oxygen.

Table E-2. SUMMARY OF WASTE STREAMS (NON-RADIOACTIVE)
RELEASED FROM IRON AND INDUSTRY²²
(Percent of total)

Geographic area	Iron manufacturing Waste sludge	Consolidated Steel plant waste	Coke Plant Raw waste
New England	0.05	0.02	0.002
Mid-Atlantic	0.05	0.33	0.33
East North Central	0.56	0.42	0.41
West North Central	0.02	0.02	0.01
South Atlantic	0.12	0.09	0.07
East South Central	0.03	0.02	0.02
West South Central	0.09	0.03	0.06
Middle	0.05	0.05	0.06
West	0.03	0.02	0.02
Total metric tons/yr	2,720	227,000	36,300

Table E-3. METAL ANALYSIS OF EMISSION TESTS (CONDUCTED IN 1973)
ON VARIOUS PROCESSES AT A MAJOR NORTHWEST STEEL PLANT²³

Source test	Cadmium ppm	Lead ppm	Zinc ppm
Sinter plant, ESP dust	13	320	820
Blast furnace, scrubber sample	14	830	9,300
Open hearth, ESP dust	250	18,000	157,000
Basic oxygen, scrubber sample	80	4,600	45,000
Electric furnace, baghouse dust	580	32,000	190,000

Table E-4. ANALYSIS OF WASTEWATER DISCHARGE FROM IRON ORE MINING AND
CONCENTRATION OPERATIONS AT ONE MILL²⁴

Constituent	mg/l
Lead	0.014
Phosphorus	0.002
Arsenic	0.005
Selenium	0.005
Copper	0.005
Iron	0.167
Manganese	1.94
Magnesium	27.6
Zinc	0.03
Chlorine	10.9
Sulfates	227.0
Phenol	0.005

^a Hardness as CaCO₃ 287
pH 7.0

Table E-5. SOURCES OF MILL WASTEWATER AT RESERVE MINING²⁸

Source	Percent of total flow 1640 liters per second (58 cfs)	Approximate suspended solids content, mg/l
Cyclone overflows	17.5	14,000
Primary flotation underflows	42.0	150,000
Regrind flotation underflows	15.5	40,000
Dewatering operations	14.5	1,000
Pellet plant	0.5	5,000
Crusher and dust collection	4.0	-
Miscellaneous	6.0	-

Table E-6. POTENTIALLY HAZARDOUS EMISSIONS
FROM COKE PLANTS²⁶

Status	Chemicals potentially present		
	Emission class	Specific components	Phase
Known present/ known hazardous	Amines	α + β Naphthyl amine 4-aminobiphenyl	Gas Gas
	Combustion gases	Carbon monoxide	Gas
	Polynuclear	Pyrene	Gas
		Chrysene	Gas
		Benzo(a)pyrene	Gas
		Benzo(e)pyrene	Gas
		Dibenzo(a,h)-anthracene	Gas
		Dibenzo(a,g)fluorene	Gas
	Organometallics	Nickel carbonyl	Gas
	Fine particulates	Tar	Gas
		Soot	Gas
Known present/ suspected hazardous	Cyanides	Hydrogen cyanide	Gas
	Acid and anhydrides	Benzoic acid	Gas
		Hydroxybenzoic acid	Gas
		Hydrochloric acid	Gas
	Amines	Ammonia	Gas
		Aniline	Gas
		Methylaniline	Gas
	Carbonyl compounds	Formaldehyde	Gas
		Acetaldehyde	Gas
		Paraldehyde	Gas
	Polynuclear	Methylchrysene	Gas
		Benzo(a)anthracene	Gas
		Dimethylbenzanthracenes	Gas
	Sulfur compounds	Methyl mercaptan	Gas
		Ethyl mercaptan	Gas

Table E-6(continued). POTENTIALLY HAZARDOUS EMISSIONS
FROM COKE PLANTS²⁶

Status	Chemicals potentially present		
	Emission class	Specific components	Phase
Suspected present/ known hazardous	Trace elements	Beryllium	Gas
		Silver metals and soluble compounds	Gas
		Mercury	Gas
		Vanadium	Gas
		Lead	Gas
		Cadmium	Gas
		Antimony	Gas
		Arsenic	Gas
		Barium	Gas
	Heterocyclics	Pyridine	Gas
		Alkyl pyridine	Gas
		Phenyl pyridine	Gas
		(Mono) Benzofurans	Gas
		Quinoline	Gas
		Alkyl quinoline	Gas
Suspected present/ known hazardous	Hydrocarbons	Aliphatics	Gas
		Olefins	Gas
		Benzene	Gas
		Toluene	Gas
		Xylene	Gas
		Alkylbenzenes	
	Phenols	Phenol	Gas
		o,m,p-cresols	Gas
		Phenyl phenol	Gas
		Alkyl phenols	Gas
		Alkyl cresols	Gas

Table E-6(continued). POTENTIALLY HAZARDOUS EMISSIONS
FROM COKE PLANTS²⁶

Status	Chemicals potentially present		
	Emission class	Specific components	Phase
	Polynuclear	Biphenyl	Gas
		Naphthalene	Gas
		Alkyl naphthalene	Gas
		Phenyl naphthalene	Gas
		Tetralin	Gas
		Methyl tetralin	Gas
		Acenaphthylene	Gas
		Acenaphthene	Gas
		Fluorene	Gas
		Alkyl anthracenes	Gas
		Phenanthrenes	Gas
		Alkyl phenanthrenes	Gas
		Coronene	Gas
		Carbazole	Gas
		Acridine	Gas
		Benzocarbazoles	Gas
		Alkylacridines	Gas
		Benzo(a)anthrone	Gas
		Perylene	Gas
	Sulfur compounds	Hydrogen sulfide	Gas
		Thiophenes	Gas
		Methyl thiophene	Gas
		Carbon disulfide	Gas
		Carbonyl sulfide	Gas
	Trace elements	Selenium	Gas
	Fine particulates	Coke	Gas
		Coal	Gas
	Cyanimides	Ammonium cyanide	Gas
		Naphthyl cyanide	Gas

Table E-7. CHEMICALS POTENTIALLY PRESENT IN EMISSIONS FROM
COKE QUENCHING AND DIRECT COOLING OPERATION²⁶

Status	Chemicals potentially present		
	Emission class	Specific components	Phase
Known present/ known hazardous	Amines	$\alpha + \beta$ Naphthyl amine 4-aminobiphenyl	Gas Gas
	Combustion gases	Carbon monoxide	Gas
	Phenols	Phenol	Aqueous
	Polynuclear	Pyrene	Gas
		Chrysene	Gas
		Benzo(a)pyrene	Gas
		Benzo(e)pyrene	Gas
		Dibenzo(a,h)anthracene	Gas
		Dibenzo(a,g)fluorene	Gas
	Organometallics	Nickel carbonyl	Gas
	Fine particulates	Tar	Gas
		Soot	Gas
Known present/ suspected hazardous	Cyanides	Hydrogen cyanide	Gas
	Acid and anhydrides	Benzoic acid	Gas
		Hydroxybenzoic acid	Gas
		Hydrochloric acid	Gas
		Sulfur acid	Aqueous
	Amines	Ammonia	Gas
		Aniline	Gas
		Methylanilines	Gas
		Ammonia	Aqueous
	Inorganic salts	Ammonium sulfate	Aqueous
	Carbonyl compounds	Formaldehyde	Gas/Aqueous
		Acetaldehyde	Gas/Aqueous
		Paraldehyde	Gas
	Heterocyclics	Pyridine	Aqueous
	Hydrocarbon	Benzene	Aqueous
		Toluene	Aqueous
		Xylene	Aqueous

Table E-7 (Continued). CHEMICALS POTENTIALLY PRESENT IN EMISSIONS
FROM COKE QUENCHING AND DIRECT COOLING OPERATION²⁶

Status	Chemicals potentially present		
	Emission class	Specific components	Phase
Suspected present/ known hazardous	Phenols	o,m,p-Cresol	Aqueous
	Polynuclear	Methylchrysenes	Gas
		Benzo(a)anthracene	Gas
		Dimethylbenzanthracene	Gas
	Sulfur compounds	Methyl mercaptan	Gas
		Ethyl mercaptan	Gas
		Thiophenes	Aqueous
	Trace elements	Beryllium	Gas
		Silver metals and soluble compounds	Gas
		Mercury	Gas/Aqueous
		Vanadium	Gas
		Lead	Gas/Aqueous
		Cadmium	Gas
		Antimony	Gas
		Arsenic	Gas
		Barium	Gas
		Selenium	Aqueous
	Organometallics	Nickel carbonyl	Aqueous
	Cyanides	Hydrogen cyanide	Aqueous
		Ammonium cyanide	Aqueous
		Ammonium thiocyanate	Aqueous
	Heterocyclics	Pyridine	Gas
		Alkyl pyridines	Gas
		Phenyl pyridine	Gas
		(Mono) Benzofurans	Gas
		Quinoline	Gas
		Alkylquinolines	Gas
		Dibenzofuran	Gas
		Alkyl dibenzofurans	Gas
	Hydrocarbons	Aliphatics	Gas
		Olefins	Gas
		Benzene	Gas
		Toluene	Gas
		Xylene	Gas
		Alkylbenzenes	Gas
	Phenols	Phenol	Gas
		o,m,p-Cresols	Gas
		Phenyl phenol	Gas
		Xylenols	Gas

Table E-7 (Continued). CHEMICALS POTENTIALLY PRESENT IN EMISSIONS
FROM COKE QUENCHING AND DIRECT COOLING OPERATION²⁶

Status	Chemicals potentially present		
	Emission class	Specific components	Phase
	Polynuclear	Alkyl phenols	Gas
		Alkyl cresols	Gas
		Biphenyl	Gas
		Naphthalene	Gas
		Alkyl naphthalenes	Gas
		Phenyl naphthalenes	Gas
		Tetralin	Gas
		Methyl tetralins	Gas
		Acenaphthylene	Gas
		Acenaphthene	Gas
		Fluorene	Gas
		Anthracene	Gas
		Alkyl anthracenes	Gas
		Phenanthrenes	Gas
		Alkyl phenanthrenes	Gas
		Coronene	Gas
		Carbazole	Gas
		Acridine	Gas
		Benzocarbazoles	Gas
		Alkylacridines	Gas
		Benzo(a)anthrone	Gas
		Perylene	Gas
	Sulfur compounds	Hydrogen sulfide	Gas
		Thiophenes	Gas
		Methyl thiophenes	Gas
		Carbon disulfide	Gas
		Carbonyl sulfide	Gas
	Trace elements	Selenium	Gas
		Arsenic (arsenic tri-oxide, sodium arsenate, sodium arsenite)	Aqueous
		Barium (acetate, chloride, nitrate)	Aqueous
		Cadmium (chloride, nitrate, sulfate)	Aqueous
	Fine particulates	Coke	Gas
		Coal	Gas
	Cyanides	Ammonium cyanide	Gas
		Naphthyl cyanide	Gas

APPENDIX F
TYPES AND NUMBERS OF STEEL FURNACES

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Table F-1. ELECTRIC DIRECT-ARC STEELMAKING FURNACES
IN THE UNITED STATES, AS OF JANUARY 1, 1970²⁷

Capacity range, net tons*	Number of furnaces
1 - 5	15
6 - 10	17
11 - 15	44
16 - 20	20
21 - 25	19
26 - 30	14
31 - 35	11
36 - 40	6
41 - 45	8
46 - 50	12
51 - 60	12
61 - 70	13
71 - 80	19
81 - 90	7
91 - 100	12
101 - 120	10
121 - 140	3
141 - 160	22
161 - 180	6
181 - 200	10
201 - 225	2
226 - 250	1
400	1
Total	284

Source: Iron and Steel Works Directory of the United States and Canada, published by American Iron and Steel Institute, New York, N.Y. (1970).

* Metric tons (1000 kg)

Table F-2. BASIC OPEN-HEARTH FURNACES IN THE UNITED STATES²⁷

(as of January 1, 1970)

Rated capacity per heat, net tons*	All types including stationary and filtering type
11 - 30	-
31 - 50	4
51 - 70	4
71 - 90	2
91 - 110	13
111 - 130	-
131 - 150	76
151 - 170	33
171 - 190	51
191 - 210	61
211 - 230	39
231 - 280	40
281 - 330	33
331 - 380	28
381 - 400	13
401 - 450	7
451 - 500	1
501 - 550	2
551 - 600	1
Tons* of open-hearth steel produced, thousands of net tons*	60,934
Percent of total raw steel production	43.2
Furnaces over 191-ton* capacity	225
Furnaces under 191-ton* capacity	183

* Metric tons (1000 kg)

Table F-3. BASIC OXYGEN PROCESS STEELMAKING FURNACES IN THE
UNITED STATES, CLASSIFIED INTO CAPACITY RANGES²⁷

(As of January 1, 1970)

Capacity range, net tons*	Number of furnaces with rated capacities within range
51 - 75	2
76 - 100	8
101 - 125	10
126 - 150	11
151 - 175	-
176 - 200	15
201 - 225	7
226 - 250	6
251 - 275	4
276 - 300	9
301 - 325	-
326 - 350	2

* Metric Tons (1000 kg)

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REFERENCES FOR APPENDICES

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